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JOSEPH HYDE PRATT, STATE GEOLOGIST

VOLUME III

THE COASTAL PLAIN OF NORTH CAROLINA

BY

WM. BULLOCK CLARK, BENJAMIN L. MILLER, L. W. STEPHENSON,
B. L. JOHNSON, AND HORATIO N. PARKER

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LETTER OF TRANSMITTAL.

CHAPEL HILL, N. C., July 1, 1911.

To His Excellency, W. W. KITCHIN,
Governor of North Carolina.

SIR:—I have the honor to submit for publication as Volume III of the publications of the North Carolina Geological and Economic Survey a report on the Coastal Plain Deposits of North Carolina. This report has been prepared in coöperation with the United States Geological Survey, under the general supervision of Dr. T. Wayland Vaughan, Geologist in charge of Coastal Plain Investigations, and under the direct supervision of Dr. William Bullock Clark, Geologist in charge of the District from New England to North Carolina. The volume has been divided into two parts. Part I treats of the Physiography and Geology of the Coastal Plain Region, and has been prepared by Dr. William Bullock Clark of Johns Hopkins University, Prof. Benjamin L. Miller of Lehigh University, and Dr. L. W. Stephenson of the United States Geological Survey. Part II, which deals particularly with the Water Resources of the Coastal Plain Region, has been prepared by Dr. L. W. Stephenson, Mr. B. L. Johnson, and Mr. Horatio N. Parker of the United States Geological Survey. It takes up in considerable detail the question of artesian water in the Coastal Plain Region, and is a report for which there is a considerable demand.

Yours very truly,

JOSEPH HYDE PRATT,
State Geologist.

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PREFACE.

The present volume deals with the geology of the Coastal Plain area of North Carolina. The formations here represented are found for the most part in adjacent States and have long been the subject of detailed study by geologists. The North Carolina area has until recently received less attention than the regions to the north and south of it, but the present study has succeeded in establishing both the sequence of the deposits and their relations to those of other areas, and thus for the first time affords a clear view of the geological history of eastern North Carolina.

The volume is divided into two parts; the first takes up the physiography and geology of the Coastal Plain region, and the second part deals with the water resources of the same region.

The first chapter of Part I, devoted to *The Physiography of the Coastal Plain of North Carolina,* contains an account of the surface features of this district, which consist chiefly of a series of dissected terraces formed during late Tertiary and Pleistocene time. The similarity of this region to that of the Coastal Plain farther north is brought out. This chapter is by Professor Clark.

The second chapter, entitled *The Stratigraphy of the Coastal Plain of North Carolina,* comprises an exhaustive study of the character and distribution of the formations of eastern North Carolina. This study has been conducted under the direction of Prof. William Bullock Clark of the Johns Hopkins University, who has charge for the United States Geological Survey of Coastal Plain investigations between North Carolina and New England. It represents the results of extended field work by Dr. L. W. Stephenson of the United States Geological Survey and Dr. B. L. Miller of Lehigh University, the former having devoted his attention to the Cretaceous and Pleistocene formations and the latter to the Tertiary formations. They had as field assistants for several months Mr. Joseph E. Pogue of the University of North Carolina and Mr. Harvey E. Bassler of Lehigh University.

Dr. Stephenson was materially aided in the study of the Cretaceous and Pleistocene formations by Mr. E. W. Berry of the Johns Hopkins University, who made an exhaustive study of the floras, having spent several months in the field, the resulting notes being turned over to Dr. Stephenson. He also profited materially by the results of the studies of Mr. B. L. Johnson, who, under the auspices of the Federal Survey, first differentiated the main features of the Pleistocene terracing in North Carolina. Dr. T. W. Stanton of the United States Geological

Survey superintended the study of the Cretaceous invertebrate fossils collected by Dr. Stephenson and made many valuable suggestions during the progress of the work.

Dr. Miller has incorporated numerous sections and other data relating to the Tertiary from the field notes of Dr. Stephenson. He has also received much aid as a result of the laboratory study of the molluscan fossils by Miss Julia A. Gardner of the Johns Hopkins University. The very extensive Mio-Pliocene faunas have entailed a prolonged study by Miss Gardner, which is not yet completed, and which when finished will form part of a contemplated series of reports dealing in detail with the geology and paleontology of the Coastal Plain portions of the State, in which the several contributors whose names have been already mentioned, as well as other specialists, will participate.

The third chapter embraces a discussion of *The Geological History of the Coastal Plain of North Carolina.* The geological events which transpired in North Carolina during the building of the Coastal Plain series of deposits are discussed in the light of the entire Coastal Plain district.

The fourth and last chapter of Part I deals with *The Correlation of the Coastal Plain Formations of North Carolina,* comparisons being instituted with the known horizons in adjacent States, as well as with the recognized series in the Gulf, and even in some instances in Europe. This chapter has been prepared by Professor Clark.

Part II deals with *The Water Resources of the Coastal Plain of North Carolina,* and consists of an extended discussion of the character of the underground water supplies and the superficial waters where used as municipal supplies. The material for this chapter was collected by the authors, Messrs. Stephenson and Johnson. The assembling of this data was made possible through the coöperation of municipal authorities, municipal water companies, well owners, and drillers throughout the region. This portion of the report is also accompanied by a chapter on *The Quality of Some Waters of the Coastal Plain of North Carolina,* by Horatio N. Parker, in which analyses are given of many of the principal waters.

Thanks are especially due to the United States Geological Survey, in coöperation with whom this investigation has been conducted. This report is one of a series being prepared by the Federal and State Surveys on the geology and water resources of the Coastal Plain, under the supervision of a joint committee of which Dr. William Bullock Clark is chairman. Dr. T. Wayland Vaughan of the United States Geological Survey is supervising geologist of the entire work.

JOSEPH HYDE PRATT,
State Geologist.

PART I

THE PHYSIOGRAPHY AND GEOLOGY OF THE COASTAL PLAIN OF NORTH CAROLINA

BY

WM. BULLOCK CLARK, BENJAMIN L. MILLER,
AND L. W. STEPHENSON.

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CHAPTER I.

THE PHYSIOGRAPHY OF THE COASTAL PLAIN OF NORTH CAROLINA.

BY WM. BULLOCK CLARK.

THE STATE.

Location and Extent.—The State of North Carolina is situated on the Atlantic seaboard between 33° 50′ and 36° 33′ north latitude and between 75° 27′ and 84° 26′ west longitude, thus having a total width from north to south of nearly 200 miles and from east to west of over 500 miles. Its eastern and western boundaries conform largely to the great natural confines of sea and mountains, the former with its curving shore line being more than 300 miles in length, while the latter trends northeast to southwest along the crest of the Appalachian Mountain system for over 200 miles. The northern and southern boundaries, on the other hand, are mainly conventional lines, the former a due east and west line about 325 miles in length and the southern a broken line about 375 miles in length. The total area of the State is 52,286 square miles, of which 3,620 square miles are water.

PHYSIOGRAPHIC PROVINCES.

The State of North Carolina constitutes a part of the Atlantic border region stretching from the crest of the Appalachian Mountain system to the sea, and is divided into three more or less sharply defined districts, known as the Coastal Plain, the Piedmont Plateau, and the Appalachian Region. These three districts follow the Atlantic border of the United States in three belts of varying width from New England to the Gulf.

The western mountainous district, known throughout the eastern portion of the country from Pennsylvania to Alabama as the *Appalachian Region,* culminates in North Carolina in a series of ranges that reach over 6,000 feet in altitude. Kerr, in describing this region, says:

"The western section is a rugged mountainous plateau; it forms a narrow, irregular, much indented trough, lying between the bifurcating chains of the western and dominant arm of the southern prolongation of the Appalachians—the Smoky Mountains and the Blue Ridge—the former being the western boundary of the State. The length of this plateau from northeast to southwest is more than 200 miles, its breadth 15 to 50 miles, and its area nearly 6,000 square miles. The Smoky chain has a general elevation of from 5,000 to 6,000 feet, rising in many summits to 6,500 feet and upwards, but is broken down by half a dozen deepwater gaps or cañons to the level of 2,000 and even 1,200 feet. The Blue Ridge, which constitutes the eastern boundary of the plateau, is a very sinuous and angular and straggling mountain chain, with a general elevation of from 3,000 to 4,000 feet and upwards, a few of its higher summits, about midway in the State, reaching nearly 6,000 feet.

"These two bounding chains are connected by many north and south cross-chains, of equal elevation with themselves, or greater, and separated by deep valleys. On one of these cross-chains, called the Black Mountains, is Mitchell's Peak, the highest point east of the Mississippi, its altitude being 6,711 feet (400 feet above Mount Washington in New Hampshire). The cross-valleys or river basins have an altitude of from 2,000 to 3,000 feet, with smaller benches and marginal plateaus of from 3,500 to 4,000 feet. Seen from the east or Atlantic side, the Blue Ridge appears as a steep, ragged, and broken escarpment, springing suddenly 2,000 to 3,000 feet above the Piedmont Plateau at its base."

The central hill country known as the *Piedmont Plateau* attains a much greater width in North Carolina than in the States to the north of it, and is also far more rugged. Kerr, in describing this area, says:

"This plateau has along its western margin an altitude of 1,200 to 1,500 feet above sea-level, and is mountainous, with high and precipitous spurs projected eastward and southward from the Blue Ridge. A few of these extend in irregular, straggling ranges all across the breadth of the Piedmont section, which is 60 to 75 miles wide, and carries an elevation of 1,000 feet to its eastern margin.

"This middle region of the State is a country of hills and valleys and rolling uplands, its prominent topographical features being a succession of broad-backed swells with eastward or southeastward trends, constituting the watersheds between a number of large rivers, which take their rise in the Piedmont or on the flanks of the Blue Ridge, and reach the Atlantic through a system of wide valleys, 300 to 500 feet below the intervening divides. The area of this region is about 20,000 square miles; its altitude, descending gradually from 1,000 to about 200 feet, averages about 650 feet."

The eastern low country, known as the *Coastal Plain,* extends from Cape Cod and the islands off the New England coast as a constantly widening belt to the Gulf. Along its western margin in North Caro-

lina it is often hilly, forming the sandhill district, the streams here frequently cutting through the softer Coastal Plain deposits to the harder rocks of the Piedmont Plateau below. The sandhills often appear as outliers on the Piedmont Plateau, where they attain elevations of from 400 to 500 feet.

To the eastward the country declines in altitude, passing from one broad plain or terrace to another until it approaches tide-level, when it embraces swamps, marshes, bays, and sounds over wide areas—the whole surface for more than 50 miles inland from Hatteras and the Eastern Shore being less than 20 feet above sea-level. The ocean is walled off from this low region by a long linear chain of sand islands or dunes, ranging from 75 to 100 feet and upwards in height and separated in half a score of places by inlets which connect the sounds with the ocean. The total width of the plain reaches 125 miles. Its area is about two-fifths that of the State, exceeding 20,000 square miles and embracing wholly or in part 42 counties.

Beyond the outer shore line the surface slopes gradually beneath the sea to the continental shelf, this belt off the North Carolina coast having a width of about 50 miles, thus constituting a submarine district of nearly 15,000 square miles.

THE COASTAL PLAIN.

The Coastal Plain is the name applied to the low and partially submerged area of varying width that is confined between the Piedmont Plateau on the west and the continental shelf on the east. Its western boundary passes through Northampton, Warren, Halifax, Franklin, Wake, Johnston, Chatham, Moore, Richmond, and Anson counties. It naturally falls into two divisions—a submerged or *submarine division* and an emerged or *subaërial division,* the seashore forming the boundary line between them. This line of demarcation, although apparently fixed, is in reality very changeable, for during the geologic ages which are past it has migrated back and forth across the Coastal Plain, at one time occupying a position well over on the Piedmont Plateau, and at another far out at sea. At the present time there is reason to believe that the sea is encroaching on the land by the slow subsidence of the latter, but the period embraced by a few generations of men is too short in which to measure this change.

The Coastal Plain of North Carolina is part of the great district which borders the ocean front from New England to the Gulf, and for the most part has been subjected to the same great physiographic changes here as elsewhere. At the same time, some marked differences are found which have left their record in the region.

THE COASTAL PLAIN STREAMS AND VALLEYS.

The Rivers and Creeks.—The Coastal Plain rivers consist of two types: first, those which rise in the Piedmont Plateau and cross the Coastal Plain on their way to the sea, and, second, those which rise in the Coastal Plain itself. In the first group belong the largest rivers of the district: the Roanoke and Chowan in the north, which have their sources in the Piedmont Plateau of Virginia; the Tar and Neuse of the central area, which rise in the eastern portion of the North Carolina Piedmont, and the Cape Fear River of the south, which has its source somewhat farther westward. Several important South Carolina rivers also have their sources in North Carolina; the Peedee, known as the Yadkin in its upper portions, and the Santee, which receives the waters of both the Catawba and the Broad rivers. All of these streams rise in the western portion of the North Carolina Piedmont, receiving their waters in part from the eastern flanks of the Appalachian Region.

Throughout the Coastal Plain are numerous small rivers and creeks as well as the lower tributaries of the big streams which have their source within the Coastal Plain itself. They are scattered throughout the district and do not need to be considered in detail in this connection.

The large rivers are tidal only in their lower courses, although they are for the most part navigable almost to the Piedmont border. The smaller streams flow generally with rather rapid currents, except near their mouths and throughout much of the low eastern district, where they, too, are tidal. Some of the tributary streams draining the higher terraces of the Coastal Plain have rapid currents, and where they have cut through the deposits of the Coastal Plain to the crystalline rocks of the Piedmont have all the essential characteristics of Piedmont streams.

The Valleys.—The valleys of the Coastal Plain district of North Carolina are not simple trenches cut out of the broad upland surface that forms the interstream areas. They have had in most instances a complicated history since they were formed during the extensive post-Lafayette emergence, which in North Carolina, as elsewhere, produced the greater river channels and conditioned the chief Coastal Plain drainage systems of the present day. During subsequent oscillations the submergence of these valleys took place and the development of the same terraces here as in the other areas went on. Each succeeding terrace-forming period left its impress on the valley topography, although all trace of the older terrace was often obliterated in the stream valley during the succeeding period of emergence.

The reëntrant valleys of the smaller streams also afford much interesting data for an interpretation of Coastal Plain history. While the

larger streams have often removed all or the larger part of the valley fillings, leaving only remnants of the accumulations along the sides, some of the smaller and less active streams have left the floors of the reëntrant valleys but slightly modified. Cases can be found where the smaller reëntrants have been practically unchanged since the enwrapping terraces buried the old valley beneath its accumulations, a signal proof of the submergence that preceded the terrace-making.

We find six generations of valleys in the Coastal Plain. The larger valleys may still contain remnants of all, but in the smaller valleys of each terrace the simplest conditions are found. Here numerous cases may be cited where streams that cut the valleys have disappeared. They will be later discussed in connection with the great terraces of which they form a part.

Toward their headwaters these valleys are narrow and V-shaped, and, if traced to their sources, are often found to start from intermittent springs, surrounded by steep-walled amphitheaters from 5 to 10 feet in height. Toward their lower courses these valleys are broad and flat and are frequently filled with fresh or brackish water marshes. In the upper portions of their courses the valleys are being eroded. In the lower portions they are being filled. A glance at the map will serve to confirm the opinion which has been held for a long time, namely, that the rivers of the Coastal Plain of North Carolina have been drowned along their lower courses, or, in other words, have been transformed into estuaries by the subsidence of the region. The filling of these valleys has taken place toward the heads of these estuaries. The headwaters of these recent valleys, on the other hand, are being extended inland toward the divides with greater or less rapidity.

Many of the tributary streams occupy the reëntrant valleys described above. The more energetic have succeeded in carrying out all of the ancient floors which formerly covered these valleys and formed a portion of the various terraces. Others have left mere remnants of these valley accumulations along the margins, while the less active streams have left the reëntrant valleys practically unmodified.

THE COASTAL PLAIN TERRACES.

The topography of the Coastal Plain presents considerable complexity, notwithstanding its low relief. This is fundamentally due to the system of terraces out of which the region is composed, although denudation and wind action have also been important factors in changing the surface configuration, the former more especially in the higher terraced region near the main stream channels and the latter near the coast. The subaërial division of the Coastal Plain contains six ter-

races, the submarine division, on the other hand, only one, which make altogether seven terraces in the Coastal Plain. In describing these terraces, the author will anticipate somewhat material which will be discussed later in another place. These terraces, beginning with the highest, are the Lafayette, Coharie, Sunderland, Wicomico, Chowan, Pamlico, and Recent.

The Lafayette Terrace.—The Lafayette terrace is represented in North Carolina by the sandhills of Scotland, Richmond, Cumberland, Moore, Harnett, Wake, Johnston, Nash, Halifax, and Northampton counties, which are dissected remnants of an ancient terrace that wrapped about the higher elevations of the eastern Piedmont, burying the western margin of the Coastal Plain and the lower portions of the Piedmont Plateau, just as the later and lower terraces in successively more easterly positions have done. The terrace features of the Lafayette, no longer clearly recognizable in North Carolina, have been described in Virginia and Maryland, where more extensive and but partially dissected remnants of the Lafayette terrace have been preserved. The extensive erosion to which the Lafayette has been subjected in North Carolina and the fact that deposits of this age have only been observed at a few points overlying the older sediments of the Coastal Plain suggest a higher elevation in post-Lafayette time with a more extensive erosion of the earlier materials than in the States directly to the north.

In Maryland where this terrace has been studied in great detail it has been found in the interstream areas to be at times as flat and featureless as the later terraces, while along the margins where it has been dissected by waterways it has been transformed into a gently rolling country and its true character obscured. Many isolated outcrops, not unlike the sandhills of North Carolina, are found in nearby areas both of the Coastal Plain and the Piedmont Plateau, which are regarded as scattered remnants of a continuous Lafayette terrace that have been brought into their present isolated position by erosion. The remnants of this plain along the ancient Piedmont shore line present approximately a common level from which point the surfaces decline gradually toward the adjacent stream channels and the ocean, as in the case of the Recent terrace of the submarine division of the Coastal Plain. In fact, the physical similarity of this terrace, as of all the later terraces of the Pleistocene to the terrace forming to-day in the estuaries and along the ocean front, is most pronounced and renders it practically certain that the conditions from Lafayette time on to the present have been in the main the same, and that, with the successive oscillations of the coast line, terraces have been formed at levels where the sea has stood for any considerable period of time.

The Coharie Terrace.—The Coharie Terrace, undeveloped in the northern Coastal Plain, is found in the region to the east of the sandhills in Scotland, Robeson, Cumberland, Harnett, Sampson, Johnston, Wayne, Wilson, and Nash counties. Along its inner edge it has elevations of 220 to 235 feet, from which it slopes gradually to the eastward, having elevations of 160 to 180 feet along its outer border, being often much broken, as in Cumberland County, toward the valley of the Cape Fear River. Broad interstream areas but little dissected occur in that part of the area south of the Neuse River. The width of the terrace, which in the larger areas reaches nearly 25 miles near the South Carolina border, gradually decreases until it apparently disappears in Halifax or Northampton counties, the last important development of it being in Nash County. It is believed that a narrow area of the Coharie terrace extends northwestward through Halifax County and possibly into Northampton.

The Sunderland Terrace.—The Sunderland terrace is found as a belt extending throughout the district from the Virginia to the South Carolina boundary, except where cut through by the reëntrants of the Wicomico terrace. Adjacent to the Coharie escarpment it has an elevation of 140 to 160 feet, from which point it gradually slopes eastward to an elevation of 110 feet and at some points may even reach 100 feet. Within the interstream areas broad undrained tracts are found, while near the margins of the terrace, especially adjacent to larger river valleys, the surface is often deeply trenched.

The Sunderland terrace is found principally in Robeson, Columbus, Bladen, Cumberland, Sampson, Duplin, Wayne, Johnston, Greene, Wilson, Edgecombe, Nash, Halifax, and Northampton counties. The area covered by the Sunderland terrace is much larger than that covered by the Coharie, and gradually increases in width to the southward. In the northern counties it is from 5 to 15 miles in width, but gradually increases to fully 25 miles in the central counties, while in the Cape Fear River district and toward the South Carolina line it is fully 40 miles wide in places.

The Wicomico Terrace.—The Wicomico terrace embraces a much larger portion of the Coastal Plain than do the Coharie and Sunderland, similarly as this terrace in more northern areas embraces more area than the Sunderland. It likewise forms deep reëntrants in the older terraces, reaching in some of the valleys nearly if not quite to the Piedmont border. This feature is especially well seen in the valleys of the Neuse and Cape Fear rivers. The elevation of the terrace near the Sunderland escarpment is from 80 to 100 feet, while up the river valleys farther to the westward it may reach 120 feet in elevation, as shown in

some of the main-stream valleys in Cumberland and Johnston counties. The elevation of the inner surface of the Wicomico terrace in the northern counties is somewhat greater than in the south, but this is doubtless due to the fact that the Wicomico terrace has, because of marine planation, encroached somewhat farther westward on the Sunderland terrace here than farther to the south. The outer margin of the Wicomico terrace is about 60 feet, except in the great tract between the Cape Fear and Neuse rivers, where its easterly extension declines to 50 feet.

The largest areas of the Wicomico terrace are found between the Chowan and Roanoke rivers in Bertie, Hertford, and Northampton counties; between the Roanoke and Tar rivers in Halifax, Edgecombe, and Martin counties; between the Tar and Neuse rivers in Pitt and Greene counties; between the Neuse and Cape Fear rivers in Lenoir, Craven, Jones, Duplin, Onslow, Pender, and Bladen counties; and south of the Cape Fear between the Waccamaw and Lumber, chiefly in Columbus County. Much the largest area is between the Neuse and Cape Fear rivers, this great interstream area, many hundreds of square miles in area and over 40 miles in width, being poorly drained and with several great swamps on its surface. Here are found the Great Dover Swamp of Craven and Jones counties, the Whiteoak Pocoson of Jones and Pender counties, the Holly Shelter Swamp of Pender County, and the large swamp tracts in southern Duplin County. To the north of the Neuse River the areas are smaller and more largely dissected and the surface has been more fully drained. Even here, especially in the extensive area between the Roanoke and Chowan rivers, numerous swamps are found.

The Chowan Terrace.—The Talbot terrace of Maryland may be divided into two terraces in North Carolina. They are called the Chowan and Pamlico terraces, from formations of the same names described in later pages of this report. The Chowan terrace lies to the east of the Wicomico terrace and also extends as reëntrants up many of the river channels, in some instances cutting entirely across the Wicomico terrace to the Sunderland terrace, thus breaking the continuity of the former. The Chowan terrace, like the Wicomico terrace, becomes more pronounced southward until it covers the larger part of New Hanover and Brunswick counties and the adjacent portions of Columbus, Bladen, and Pender counties. Farther to the northward it is found extensively developed in Onslow, Jones, and Pamlico counties and in adjacent portions of Carteret and Craven counties. Still farther northward it appears in Beaufort, Pitt, and Martin counties, and extending up the Tar River valley into Edgecombe County. It is also found extending from Martin and Bertie counties on either side of the Roanoke River valley

into Halifax and Northampton counties. It likewise covers considerable areas in Hertford, Chowan, and Gates counties, both to the east and west of the Chowan River valley. Along the eastern margin of the Wicomico terrace, from which it is often separated by a pronounced escarpment, it has an elevation of from 40 to 50 feet which up the reëntrant valleys often rises to 60 feet or more in elevation. It gradually declines eastward to about 30 feet near its seaward face. It has a width of 20 to 25 miles, somewhat more in the south than in the north, where it is also much more dissected than the Pamlico terrace. The larger areas in the southern counties are also on the whole less fully drained than in the north. In Columbus and Brunswick counties extensive swamps are found, including Green Swamp, a large undrained area containing Waccamaw Lake.

The Pamlico Terrace.—The Pamlico terrace covers a large area to the east of the Chowan in the northern coastal counties to the north of Cape Lookout, while to the south of this point it is continued only in a narrow belt along the coast. In the valley of the Neuse and farther northward, especially in the Pamlico, Roanoke, and Chowan valleys, it extends as deep reëntrants up the channels of the several streams. It covers the entire area of Hyde, Dare, Tyrrell, Currituck, Camden, and Pasquotank, together with much of Perquimans, Chowan, Washington, Beaufort, Pamlico, Craven, and Carteret counties. Its elevation along the base of the Chowan escarpment is about 20 feet, from which point it slopes eastward to almost tide-level, and in the outer tier of counties in places seems to merge into the Recent deposits. The surface of the Pamlico terrace is covered over wide areas with swamps and marshes and embraces many estuaries, sounds, and bays. Many of the swamps along the rivers are on the Pamlico surface, as are also the Great Dismal Swamp of southern Virginia and northern North Carolina and the remarkable Mattamuskeet Lake of Hyde County, which is 16 miles long by 5 miles broad and has a depth of only 4 feet. The lower elevations of the Pamlico are also extensively covered with peaty bogs which may well prove of economic significance. The width of the Pamlico terrace exceeds 50 miles between Pamlico and Albemarle sounds. In the southern part of the State, in New Hanover and Brunswick counties, on the other hand, it is a very narrow strip and is confined to the lower courses of the Cape Fear and Northeast Cape Fear rivers.

THE BEACHES, REEFS, SPITS, AND SAND DUNES.

The coastal border contains beaches, reefs, spits, and sand dunes. The inner beaches are narrow and sandy and frequently along the sounds are simply swampy lands that extend gradually below water level. They have been everywhere protected from the action of the

open sea by an almost continuous series of low-lying islands that accompany the entire coast from the Virginia to the South Carolina line as fringing reefs. These reefs are built up on the floor of the submarine division of the Coastal Plain, where the currents have deposited materials brought down by the streams and where its breakers and undertow, by their mutual reaction, have caused a great reef to be heaped up parallel to the general trend of the shore line. Cobb,* in describing the reefs, says:

"The strong winds of midwinter come from the north, and the gentler steady winds of midsummer and of the greater part of the year blow usually from a little west of south. * * * The strong north winds pile the sands up into great barchanes or medanoes, crescentic sand dunes known locally as whaleheads, which are moving steadily southward. These are best developed along the Currituck Banks, from Virginia as far south as the Kill Devil Hills, and numbers of them may be seen to the north and to the south from the top of Currituck Light. These whaleheads are composed of singularly homogeneous blown sands, the horns or cusps of the barchanes pointing to leeward, which is almost due south.

"The prevailing winds from a little west of south have rippled the heterogeneous sands on Hatteras just south of the cape, on Shackleford at its southwest extremity, and on the southwest side of Smith's Island. These wind ripples, started in sands exposed by the removal of a strip of forest next to the shore, have grown in size to great sand waves, which are advancing on forests, fields, and homes. As the sand wave has advanced it has taken up several feet of the loose soil over which it has passed, undermining houses, laying bare the roots of trees, and exposing the bones of the dead in the cemeteries.

"Diurnal winds from the sea have piled the sands into small wandering dunes and hillocks, and even sometimes into sand waves, which are marching steadily inward and shoaling the waters of the sounds. At Nag's Head a large hotel, constituting a solid obstruction, soon had a sand wave built up a short distance in its rear until the level of its roof was reached, when the wave moved forward and engulfed the hotel. In the immediate neighborhood two cottages suffered a similar fate. Here the land gained on the sound 350 feet in ten years.

"On the northern end of Hatteras Island a fishing village has been similarly buried, while the sand has entirely crossed the island at several places north of the cape. This movement of the sand was started just after the Civil War by the cutting of trees next the shore for ship timbers, and the section is still known as The Great Woods, though not a stick of timber stands upon it to-day. Pamlico Sound for two miles from the Hatteras shore is growing steadily shallower from the deposit of blown sand.

"On Smith's Island a pilot's village has been buried beneath the sand wave for a number of years, but this has been quite recently resurrected and its houses are again occupied. On Currituck, below Caffey's Inlet life-saving station, the sand has advanced entirely across the land, and one man, moving before the advancing sand, has at last built his house on piles in the sound.

*Natl. Geog. Mag., vol. XVII, No. 6, June, 1906, pp. 310-317.

"The writer has found by experiment that heterogeneous sands, consisting essentially of quartz, orthoclase, some mica, iron, bits of shell, and many mineral substances, showing little if any decomposition, ripple readily in the wind and are easily arrested * * *; but so far he has found no means of checking the movement of homogeneous sands that do not ripple, these consisting entirely of well-rounded and wind-sorted quartz grains of the same size throughout a single dune. * * * As already pointed out, the movement of these sands was in every case started by the deforesting of a strip of land next the shore; but in several instances nature has herself grown forests on dune sands. Above Kitty Hawk Bay large dunes are covered with a growth of pine, maple, oak, cedar, sassafras, elm, locust, beech, persimmon, sycamore, hickory, and, in the damp interdune areas, gums and cypresses. Here are many veteran pines, some of them having attained a diameter of three feet. An essentially similar forest is found growing on the high dunes to the southwest of Cape Hatteras, but here we have to add the olive to the list, and there are broad interdune palmetto swamps.

"On Bogue Banks, where deforesting has only just begun at two points, we have 20 miles of woodland, the virgin forest extending down to the water's edge and preventing the formation of dunes.

"From Southport westward into South Carolina the dunes have moved northward and inland, in some places completely filling the lagoons. At one point such a filled lagoon has produced a pine forest in something more than forty years.

"The checking of these moving dunes presents a problem of increasing importance, not only to the inhabitants of these sand keys, but to the navigators of the inland waterways as well."

The reefs reach a very much higher elevation than the adjacent mainland. The great dunes formed on these reefs attain in Dare County, in the Kill Devil Hills near Collington, an elevation of 100 feet or more, the sand being driven from them gradually shallowing Pamlico Sound. At many other points along the reefs the dunes reach 50 to 75 or more feet in elevation. Many such elevations, both large and small, are found on the Currituck banks in Currituck County.

From some points spits are developed by the shore currents, notably from Cape Lookout southward.

CHAPTER II.

THE STRATIGRAPHY OF THE COASTAL PLAIN OF NORTH CAROLINA.

BY

WM. BULLOCK CLARK, BENJAMIN L. MILLER, AND
L. W. STEPHENSON.

INTRODUCTION.

BY WM. BULLOCK CLARK.

The geology of North Carolina as well as its physiography shows an intimate relationship to the adjacent areas on the north and south, so that its complete interpretation can be gained only by taking into consideration the great eastern border region of which the State is not only geographically but geologically a part. Frequent references will, therefore, be made in the succeeding pages to the general distribution and relations of the geological formations found represented within the limits of the State, although the detailed description will be confined to those features particularly characteristic of the North Carolina area. The most ancient rocks which make up the earth's crust as well as those still in the process of deposition are found within the State's confines, while between these wide limits there is hardly an important geological epoch which is not represented.

Geology in its broadest aspects must be regarded as the science of the earth from its earliest beginnings down to the present day, and as such stands in close relationship to the science of astronomy in its study of the origin of the solar system. In the absence of any other satisfactory theory, most geologists to-day accept the nebular hypothesis of Kant and Laplace to explain the evolution of the solar system. According to this hypothesis, the solar system was developed from a mass of nebulous matter, which extended far beyond the present orbit of the most distant planet, and was rotating slowly in the direction in which the planets now rotate. As a result of rotation this mass gradually contracted and increased in speed of rotation. It was formerly thought that successive rings were thrown off which broke and contracted into

the present planets; but by analogy with the many nebulæ which have become known in the last fifty years, it is now thought more probable that the planets originated in special points of condensation of the nebula. Comparisons of the spectra of the comets and nebulæ with those of meteors led Sir Norman Lockyer to the view that these bodies were made up of swarms of meteors whose temperature was raised by impact among themselves; and he contended that the solar system had its origin in such a swarm. Prof. George H. Darwin showed that such a swarm would probably act practically like a mass of gas and that the solar system under this hypothesis would develop in exactly the same way as under the hypothesis of a gaseous origin, a high temperature being caused by the impact of the meteors analogous to that produced by the contraction of the gas. This modification of the nebular hypothesis does not require any material change in the history of the solar system. As contraction and condensation proceeded, the ancestors of the planets became hotter and hotter, and finally reached a stage like that of our present sun; as they became still denser, their power of condensation diminished, and their comparatively small masses have allowed them to cool sufficiently to become solid, though the immense sun still retains enough heat to keep it in a gaseous or liquid state. In the case of the earth, as it continued to cool it is probable that the solid rock first formed at the surface, but on account of its greater density, sank through the underlying liquid, and gradually built up a solid foundation from the center to the surface. The very small conductivity of rock for heat has only allowed a very thin shell of the earth near the surface to cool appreciably below the temperature at which it first solidified. This view has been largely strengthened by the calculations of Lord Kelvin, who, assuming that heat had not been developed within the earth since its solidification in sufficient quantities materially to alter the temperature gradient near the surface, showed that the well-known increase of temperature underground could only be accounted for on the supposition that the earth was at one time hot enough to be liquid. Within a few years Prof. T. C. Chamberlain has advanced the suggestion that the earth was built up by the accumulation of meteors which fell at such a slow rate that the heat of impact was dissipated *pari passu*, and that the internal heat of the earth is due to the compression of the earth under the weight of its own parts. Still more recently Prof. E. Rutherford has suggested that the internal heat is produced by the radio-active substances distributed throughout the earth, and the Hon. R. J. Strutt has shown that it is only necessary for these substances to be distributed to a depth of 45 miles with the density they have at the surface to account for the observed heat. The last two

hypotheses deny the assumption which is the basis of Lord Kelvin's calculations, and thus cast discredit on the resulting age of the earth; but under any hypothesis we are forced to believe that many millions of years have passed since life first appeared on the earth. We get still further conception of the vast lapses of time which these early rocks imply, when we discover that, even after the waters had become suited for living beings, a greater part of the development and differentiation of organic life went on in forms which have left no trace of their existence. Hardly a more remarkable fact confronts us in geology than the variety and the complexity of types in the earliest rocks which contain any trace of life at all. The fact which is all the more remarkable for being attested by the best evidence from all parts of the earth's surface, compels us to assign to the history of life before its first permanent record was made, a longer period perhaps than all the time that has since elapsed, unless the view more recently advanced, that acceleration of development took place in the case of the earliest sea-floor dwellers, is shown to be true. The earlier forms were either unsuited for preservation or else they have been obliterated in the subsequent alteration of the rocks containing them.

All of the oldest rocks which are to-day entirely without, or with only slight traces of former life, are referred to the first great division of geological history called *Archean Time*. These oldest rocks are largely crystalline in character, so that there can be but little chance of encountering organic forms, even had they earlier existed in the strata. Even the least altered deposits, although they have afforded a few scattered remains of archaic forms at certain points, contain nothing more than the merest traces of the organisms of this early time.

When, however, life does once appear in all its variety, it is well-nigh the same in all the older rocks. In the most widely separated localities the same types occur in rocks of the same age, and this furnishes us with the key to the succession of deposits. From the time when the oldest fossil-bearing stratum was deposited until now, the story of life-progress and development is told by the rocks with sufficient clearness to be unmistakable. Local differences of conditions have probably always prevailed, as they do now, but the same types of organisms have always lived at the same time over the entire globe, so their remains serve as sufficient criteria for the correlation of the strata which contain them. The sequence of life forms once made out gives us, for the whole earth, the means for fixing the order of deposits, even when this is most profoundly disarranged by foldings of the strata into mountains or by other earth movements.

Geologists distinguish three principal divisions in the history of life as read in the record of the rocks. During the earliest of these great time divisions, archaic forms of life flourished—uncouth fishes, crustaceans, mollusks, and tree-ferns—most of them very unlike those now extant. On this account this is known as the period of most ancient life, or *Paleozoic Time.* To this succeeded a long lapse of ages when enormous reptiles predominated, associated with other types more like those that now inhabit the globe. To this is given the name of middle life, or *Mesozoic Time.* Finally, living things began to assume the form and appearance with which we are familiar, so that this last grand time division, which includes the present, is designated as the period of recent life, or *Cenozoic Time.*

Each of these three grand divisions of geologic time is in its turn separated into shorter subdivisions called *Periods,* characterized by their own peculiar types of life; and the several periods themselves are divided into *Epochs,* which vary more or less in character according to the region where they are developed. For this reason the chronological and stratigraphical divisions require an independent nomenclature, although this duality of geological classification can in most instances be readily adjusted to the contingencies of each district. The stratigraphical divisions are usually designated by local terms.

There are representatives not only of each of these great time divisions in North Carolina, but also of most of the periods as well as of many of the epochs.

The Piedmont Plateau and Appalachian Region contain representatives of the Archean, Paleozoic, and earliest period of the Mesozoic, while the Coastal Plain contains representatives of the latest period of the Mesozoic and the Cenozoic. The following tables give the sequence of Coastal Plain formations of North Carolina described in detail in later pages:

CENOZOIC.

QUATERNARY:

Recent,

Pleistocene—Pamlico
Chowan
Wicomico
Sunderland
Coharie } Columbia Group.

TERTIARY:

Pliocene—Lafayette
Waccamaw.

Miocene—Yorktown } north of Hatteras axis.
St. Marys }
Duplin (south of Hatteras axis).

Eocene—Castle Hayne.
Trent.

MESOZOIC.

CRETACEOUS:

Upper Cretaceous—Peedee.
Black Creek.

Lower Cretaceous—Patuxent.

These Coastal Plain formations stand in marked contrast to the formations in other parts of the State, in that they have been but slightly changed since they were deposited. Laid down one upon another along the eastern flank of the Piedmont Plateau when the sea occupied the present area of the Coastal Plain, these later sediments form a series of thin sheets which are inclined slightly seaward, so that successively later formations are generally encountered in passing from the inland border of the region toward the coast. Oscillation of the sea floor with considerable variation both in the angle and direction of tilting went on, however, during the periods of Coastal Plain deposition, with the result that the stratigraphic relations of these formations, which generally have been held to be of the simplest character, possess in reality much complexity. Viewing the Coastal Plain as a whole, we find at no place accessible to our study a complete sequence of deposits, although sedimentation must have been going on continuously along the continental shelf. The incompleteness, therefore, must be regarded as a purely marginal condition due to the retrogressions and transgressions of the sea along the coastal border.

It is not uncommon to find in any particular region marked breaks in the sequence of sedimentation, the absent members being present perhaps only a short distance away. A number of instances of this kind are shown in the Coastal Plain district of North Carolina, which lack formations that appear in Virginia on the north and South Carolina on the south, while formations found in North Carolina are lacking in those States. Not only is this true as regards North Carolina and adjacent States, but also in different portions of the North Carolina Coastal Plain itself, particularly when the region to the north of the Hatteras axis is compared with that to the south, which will be fully discussed in a later portion of this report.

A brief discussion of the main divisions of the Coastal Plain is presented here preliminary to the detailed descriptions which will follow.

MESOZOIC.

The Mesozoic formations are the basal deposits of the Coastal Plain, and they consist chiefly of sands, clays, and marls, for the most part unconsolidated. They include strata of Cretaceous age and certain basal beds that may be possibly Upper Jurassic, although there seems to be a growing belief on the part of geologists and paleontologists that the Mesozoic deposits of the Coastal Plain may be wisely considered as of Cretaceous age throughout, notwithstanding the claims hitherto made by certain leading authorities in vertebrate paleontology that the reptilian remains of the lower beds are Jurassic in their affinities.

CRETACEOUS.

The Mesozoic deposits will be considered in subsequent pages to belong entirely to the Cretaceous period. They constitute the largest element in the Coastal Plain series. The formations represent both the Lower and Upper Cretaceous.

Lower Cretaceous.

The Lower Cretaceous is represented from Maryland southward to the Gulf by formations consisting of gravels, sands, and clays. The arenaceous beds are often arkosic throughout this region and the deposits are stained by the hydrous oxides of iron and in some instances cemented to form a sandstone. They are extensively cross-bedded. The clays, which are at times very plastic and at other times more or less arenaceous, occur in large and small lenses. They have been extensively employed for economic purposes and many industries are based on them. Lignitic deposits frequently occur, and to the north iron ore beds also are found, which in Maryland were the chief source of the iron of colonial days.

The fossils of the Lower Cretaceous consist of dinosaurian and plant remains, the latter being mainly ferns, cycads, and conifers in the lower beds, with an increasing number of conifers toward the top of the series.

The Lower Cretaceous deposits in North Carolina are confined to the Patuxent formation, which consists of clays and sands, the latter prevailingly arkosic. A small amount of lignite has also been observed. No determinable fossils have been secured.

Upper Cretaceous.

Upper Cretaceous deposits are found from Massachusetts and the islands off the south coast of New England to the Gulf. They consist of gravels, sands, clays, and marls, the latter frequently glauconitic. The lower portions of the Upper Cretaceous series, although unconformable everywhere so far as known to the underlying Lower Cretaceous formations, are not unlike the older deposits in many respects, although in general less arkosic. The fossils are chiefly the remains of dicotyledonous types of plant life.

The higher beds are widely glauconitic, are rarely cross-bedded and at times contain such a large admixture of shell remains as to be highly calcareous, such deposits in places becoming indurated to form limestone ledges. The fossils in these upper beds consist largely of the remains of dinosauria, mollusca, bryozoa, brachiopoda, echinodermata, and foraminifera. At some points an intergradation of the lower into the upper type of deposit appears, while at other points the change is clearly marked.

The Upper Cretaceous deposits in North Carolina have been divided into two formations known under the names of Black Creek and Peedee, the former consisting of sands and clays thinly laminated, with interstratified beds of marl in the upper portions, and the latter consisting largely of argillaceous sands, more or less glauconitic, and with beds here and there highly calcareous. The fossils of the Black Creek formation consist of plant remains, especially of conifers and dicotyledons, and in the upper beds also of dinosaurian bones and coprolites, fish teeth and molluscan shells. The fossils of the Peedee sand consist of reptilian bones and fish teeth and the remains of mollusca, bryozoa, echinodermata, foraminifera, and other groups, showing a distinctly marine facies.

CENOZOIC.

The Cenozoic deposits overlie the Mesozoic formations, and although collectively possessing less thickness than the underlying Mesozoic, are much more conspicuous in surface outcrop than the older beds. Like the latter, they consist chiefly of sands, clays, and marls; but as their origin is in most instances different, they are commonly distinct in lithologic character. The older Cenozoic beds are in places strikingly similar to the later Mesozoic, but the later Cenozoic deposits are quite different. The sands, except in the very latest Cenozoic formations, are rarely cross-bedded and the arkosic character is absent. The beds, however, are prevailingly unconsolidated, although ferruginous and calcareous strata now and then occur.

TERTIARY.

The Tertiary deposits consist of sands, clays, and marls, the last being highly glauconitic at the lowest horizons and calcareous higher in the series. They represent the Eocene, Oligocene, Miocene, and Pliocene periods. Oligocene strata are apparently absent from the middle and northern Coastal Plain regions, and therefore will not be further considered in this connection.

Eocene.

Deposits representing different horizons of the Eocene are found scattered more or less irregularly either along the eastern margin of the Cretaceous formations or as the result of transgression as isolated outcrops on the surface of the Cretaceous or even beyond the latter on the crystalline rocks of the Piedmont Plateau. The older Eocene deposits, which are largely sands, are highly glauconitic, in this respect showing a marked similarity to the Cretaceous beds below. The later Eocene deposits lose their glauconitic character and become often highly calcareous, the materials frequently being indurated by the calcareous cement. A profuse infralittoral fauna, chiefly representing the mollusca, bryozoa, echinodermata, zoantharia and foraminifera with fish teeth and reptilian bones and coprolites, is found.

The Eocene deposits of North Carolina consist of the later facies of Eocene sedimentation. They are highly calcareous and often indurated and occur irregularly scattered over the surface of the Cretaceous formations and even transgressing the latter onto the Piedmont Plateau. They often occur in depressions in the Cretaceous surface where they have withstood the erosion to which the rest of the deposits have been subjected, since there is every reason to believe that the Eocene beds had a much wider extent formerly and that the present isolated outcrops are merely remnants of a continuous or nearly continuous sheet. The Eocene deposits of North Carolina are all to the south of the Hatteras axis, as far as known. They are divided into the Trent and Castle Hayne formations, the relations of which are unknown from any observed contact, except in a single well boring, but they are probably unconformable, just as the Eocene deposits are unconformable everywhere in North Carolina to the underlying Cretaceous. Fossils of infralittoral marine types are numerous, although the molluscan forms are with difficulty determined because they occur largely as imperfect casts.

Miocene.

Miocene deposits constitute a thick mantle over the eastern margin of the older formations throughout much of the Coastal Plain area and

in some places transgress them onto older formations. They are unconformable to the underlying Eocene. The Miocene deposits consist of sands, clays, marls, and diatomaceous earth beds. Glauconitic materials are rarely found, and when found are probably derived from older formations. The diatomaceous earth is most strikingly developed in the basal Miocene formations of Virginia and Maryland, where it has been known as "Richmond earth." The calcareous marls are at times cemented into limestone ledges. The fossils consist chiefly of littoral and infralittoral forms in which the cetacea, mollusca, bryozoa, echinodermata, zoantharia, foraminifera, and diatomacea are chiefly represented.

The Miocene deposits of North Carolina belong to the later facies of Miocene sedimentation, the littoral phase being well developed in the Yorktown formation to the north of the Hatteras axis and in the Duplin formation to the south of the Hatteras axis, where the shell remains are much broken by wave action. In the underlying St. Marys formation of the former area—the only other Miocene formation found in North Carolina—the moderately fine argillaceous sands are of a distinctly infralittoral character. They rest unconformably on Eocene or Cretaceous beds as the case may be. The fossils of the North Carolina Miocene are varied and numerous.

Pliocene.

Pliocene or supposed Pliocene deposits of two very marked types occur in the Coastal Plain region. The first is an infralittoral marine deposit not known with certainty to occur to the north of Cape Hatteras, although a detailed study of well borings may show it to overlie the Miocene beds toward the coast beneath the mantle of Pleistocene deposits. To the southward this phase of the Pliocene is, however, well developed and its characters are not unknown. The deposits of this type, however, lie as far as known along the eastern margin of the subaërial division of the Coastal Plain in somewhat detached basins. It is called the Waccamaw formation in North Carolina, where it is chiefly found in the region near the mouths of the Neuse and Cape Fear rivers. The isolated outcrops are probably remnants of a once continuous deposit. Whether the poorly developed Croatan deposits should be included cannot be determined with our present knowledge of those beds.

The second phase is a littoral and sublittoral phase, the exact age of which in the absence of fossils has never been satisfactorily determined. It is evidently of late Tertiary or early Quaternary time. It consists of gravels, sands, and loams which were evidently laid down close to

land the border of which it enwrapped, forming a terrace-like deposit. This formation is widely known to-day as the Lafayette formation from the Gulf to Pennsylvania, where the last remnants occur. In North Carolina the Lafayette is largely represented in the "sandhills" along the eastern margin of the Coastal Plain.

QUATERNARY.

The Quaternary deposits south of the terminal moraine of the continental ice sheet consist chiefly of the great Pleistocene terraces covering the larger portion of the Coastal Plain area and the Recent beaches, sand dunes, bars, and spits along the coastal border. Just below tide in the estuaries and along the coast is the Recent terrace which is now in process of formation and which affords such convincing proof of what transpired during preceding Pleistocene time in the relatively slight oscillations to which the Coastal Plain was then subjected.

Pleistocene.

The Pleistocene formations of the Coastal Plain are collectively known as the Columbia group. With the exception of the Recent deposits, they are the youngest of the Coastal Plain sediments. They lie on the surface and form a thin mantle that conceals from view all of the older formations over wide areas. Wherever found along the Atlantic border south of the terminal moraine, they are developed as more or less clearly defined terraces. Throughout the northern part of the region three well marked levels appear, while in North Carolina the upper and lower show subdivisions indicating intermediate periods of rest in the oscillatory movements of the sea in this area that have not been recognized farther northward. The deposits consist of gravels, sands, and loams, with ice-borne bowlders adjacent to the courses of the more northern streams.

The North Carolina Pleistocene deposits comprise five clearly defined terrace formations, known as the Coharie, Sunderland, Wicomico, Chowan, and Pamlico, which have been developed at successively lower levels throughout the Coastal Plain area of the State. The Talbot formation of the northern Coastal Plain is the equivalent of the Chowan and Pamlico, the subordinate terrace levels not having been recognized in the more northern areas.

Recent.

The Recent formations embrace, first, those aqueous deposits that are being laid down to-day over the submarine portions of the Coastal Plain and in the estuaries, sounds, bays, and lakes and along the various

streams, and, second, such terrestrial deposits as dunes and humus. In short, all deposits which are being formed at the present time under water or on the land by natural agencies belong to this division of geological time. All of these Recent deposits are being formed in various portions of the North Carolina Coastal Plain and collectively afford an ever increasing volume of deposits that represent the influence of the forces now active.

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1791.

Bartram, William.—*Travels Through North and South Carolina, Georgia, East and West Florida, the Cherokee Country, etc.* 520 pp., 6 pls.; Philadelphia, 1791; London, 1794.

Describes physical features, soils, vegetation, etc., from the South Carolina line in Brunswick County, northward along Cape Fear River to Cambleton [Fayetteville], and thence northeastward to the Virginia line.

A bluff at Ashwood on Cape Fear River, which was situated 3 or 4 miles below the present site of Whitehall, is described in considerable detail (pp. 472-479).

1809.

Maclure, William.—*Observations on the Geology of the United States, Explanatory of a Geological Map.* Amer. Phil. Soc. Trans., vol. 6, pp. 411-428, map, 1809. Jour. de Physique, vol. 69, pp. 204-213; vol. 72, pp. 137-165, map, 1811.

The boundaries of the Atlantic Coastal Plain are defined with considerable accuracy, the strata constituting it being referred to the "Alluvial formation." The author states that it contains beds of shells.

1818.

Maclure, William.—*Observations on the Geology of the United States, etc.* Amer. Phil. Soc. Trans., vol. 1, new series, pp. 1-91, map, plates 1-2. Philadelphia, 1818. Published separately, Philadelphia, 1817. Zeitsch. Mineral. (Leonhard), vol. 1, 1826, pp. 124-138.

The whole Coastal Plain is included in the author's "Alluvial formation," which consists of peat, sand, gravel, bog iron-ore, shell marls, and, in a few places, limestone.

1820.

Hayden, Horace H.—*Geological Essays;* or an inquiry into some of the geologic phenomena to be found in various parts of America and elsewhere. Baltimore, 1820, 412 pp.

The origin of the deposits of the Coastal Plain is attributed to a mighty flood of waters which swept across the North American continent from the northeast to the southwest. The currents transported the materials from the interior of the continent and deposited them in their present position in the Coastal Plain region.

1821.

DICKSON, JOHN.—*Notices of the Mineralogy and Geology of Parts of South and North Carolina*, in a letter to the Editor. Amer. Jour. Sci., 1st ser., vol. 3, 1821, pp. 1-4.

The Carolinas are divided into three regions—the sandy region, the clay country, and the mountains. The sandy region is practically coextensive with the Coastal Plain. The topographic features and character of the surface soils are briefly described.

1822.

OLMSTED, DENISON.—*Descriptive Catalogue of Rocks and Minerals Collected in North Carolina*. Amer. Jour. Sci., vol. 5, pp. 257-264, 1822.

Brief references are made to marly limestones in Wayne County and an extensive bed of gray compact limestone on the lower Cape Fear, "where it is burnt for lime."

1827.

MITCHELL, ELISHA.—*Report of the Geology of North Carolina*. Conducted under the direction of the Board of Agriculture. Pt. III, Raleigh, 1827, 27 pp.

The origin of the low country of North Carolina is discussed, and the conclusion reached that "it is, compared with the secondary formations of other countries, of recent date."

He mentions the occurrence of blue marl in great abundance on the banks of Northeast Cape Fear River a little below the village of South Washington. Brief statements are made concerning the marls of Bladen, Brunswick, New Hanover, Duplin, Halifax, and Hertford counties. He recognized the fact that the strata of the Coastal Plain were not all of the same age, though he did not refer them to any definite periods. The oldest marl beds which he describes are now referred to the Eocene or the Cretaceous, while the later ones are Miocene or Pliocene.

MITCHELL, ELISHA.—*Geological Report on North Carolina*. Papers on agricultural subjects, conducted under the direction of the Board of Agriculture, 1827, pp. 101-108. Raleigh.

Marl is reported from the Tar River, while "fine clay, marl, shell limestone, and iron pyrites" are said to be abundantly, as well as extensively, distributed through the "Low Country."

OLMSTED, DENISON.—*Report on the Geology of North Carolina*. Conducted under the direction of the Board of Agriculture. Part II, 1827, pp. 87-141. Abst., Am. Jour. Sci., vol. 14, pp. 230-251, 1828.

The author describes green sands containing fossil wood which occur on Neuse River in Wayne County. Similar materials are said to extend for 100 miles along the river. These are now known to be of Cretaceous age (pp. 98-99).

Descriptions are given of the [Eocene] limestones which occur along the Trent River, in Craven and Jones counties, in the Sarpony Hills, and at Bass' Ferry, near the mouth of Falling Creek, on the Neuse River. They have been burned for lime or used for construction purposes. He also

describes (Miocene) materials along the Neuse River below New Bern and on the Tar River, near Tarboro, and the (Pliocene) marl along the Beaufort Canal. All of these materials are described merely as marls or limestones, with no discussion of their age or correlation.

VANUXEM, LARDNER.—See S. G. Morton *(Geological Observations on the Secondary, Tertiary, and Alluvial Formations of the Atlantic Coast of the United States of America).*

1828.

MITCHELL, ELISHA.—*On the Character and Origin of the Low Country of North Carolina.* Amer. Jour. Sci., vol. 13, pp. 336-347, 1828.

The author combats the view, apparently common at that time, that the Coastal Plain materials were accumulated by the currents of the Gulf Stream, and also the view of Hayden, published in 1820, that they were transported by a great flood from the northeast, and comes to the conclusion that "the strata of the low country were formed in the bed of the sea, and this district became dry land either by a depression of the level of the ocean or by the elevation of its bed, by a force operating from beneath." He believes that the "low country" is made up of recent strata, as evidenced by the character of the shells. He refers to the discovery of the remains of both the mastodon and the elephant in digging the Clubfoot and Harlow Canal, near the mouth of the Neuse River. The deposits of marl at the Natural Well, at Wilmington, and at Rocky Point, are briefly described.

1829.

MORTON, SAMUEL G.—*Geological Observations on the Secondary, Tertiary, and Alluvial Formations of the Atlantic Coast of the United States of America.* (Arranged from the notes of Lardner Vanuxem.) Acad. Nat. Sci., Phila., Jour., vol. 6, 1829, pp. 59-71.

In this report the author names the localities south of Delaware in which the "Secondary" strata had, up to that time, been observed to occur, as follows: Ashwood, near the Cape Fear River, North Carolina [3 or 4 miles below Whitehall]; Mars Bluff, on the Peedee River; Effinghams Mills, Florence County, South Carolina; near the Eutaw Springs, Berkeley County, South Carolina [now known to be Eocene]; and Cockspur Island, near the Savannah River, South Carolina [likewise an Eocene locality].

1832.

CONRAD, T. A.—*Fossil Shells of the Tertiary Formations of North America.* Vol. 1, No. 1, 20 pp., 6 pls., Phila., 1832. Republished by G. D. Harris, Washington, 1893.

The Tertiary deposits of North Carolina are referred to the "Upper Marine" or "Upper Tertiary." *Arca limula, Arca transversa,* and *Cypricardia arata,* from New Bern, are described and figured.

1834.

CONRAD, T. A.—*Observations on the Tertiary and More Recent Formations of a Portion of the Southern States.* Acad. Nat. Sci., Phila., Jour., vol. 7, pp. 116-129, 1834.

The Miocene deposits at Wilmington are referred to the Pliocene, while the Eocene is not mentioned.

"The deposit therefore, at Vance's Ferry, is probably very limited in extent and extremely superficial, capping the Cretaceous rocks in the same manner as at Wilmington, North Carolina, where a patch only a few feet thick reposes on the zoophytic secondary rocks."

HARLAN, R.—*Critical Notices of Various Organic Remains Hitherto Discovered in North America.* (Read May 21, 1834.) Trans., Geol. Soc. Pa., vol. 1, Pt. I, 1834, pp. 46-112. Med. Phy. Researches, 1835. (With a few additions.)

Quotes from Cuvier's "Theory of the Earth," by S. L. Mitchell, in regard to the skeleton of a huge animal found on the bank of the Meherrin River, near Murfreesborough. The vertebral column recovered measured 26 feet and both tail and head were absent. Harlan says: "We have recognized them as the remains of a gigantic species of shark." Were probably the remains of a whale.

MORTON, SAMUEL G.—*Synopsis of the Organic Remains of the Cretaceous Group of the United States.* Philadelphia, 1834, 88 pp., 19 pls.

Describes the mineralogical and organic characters of the Cretaceous and indicates briefly its known geographic extent in North America. The "Secondary or Cretaceous group" is included in the divisions, the *Ferruginous sand* and the *Calcareous strata.* The synopsis proper consists of descriptions, arranged in systematic order, of the known organic remains of the Cretaceous, including vertebrates and invertebrates.

1835.

CONRAD, T. A.—*Fossil Shells of the Tertiary Formations of North America.* Vol. 1, No. 3, pp. 29-58, pls. 15-18. Phila., 1835. Republished by G. D. Harris, Washington, 1893.

The Tertiary deposits near New Bern are referred to the "Newer Pliocene."

CONRAD, T. A.—*Observations on a Portion of the Atlantic Tertiary Region.* Geol. Soc. Pa., Trans., vol. 1, pp. 335-341, 1835.

The author states that he was in error in his previous statements concerning the existence of the Miocene in the United States. He asserts that all Tertiary deposits above the Eocene belong to the Pliocene, which is divisible into the "Older" and "Newer" Pliocene. Brief mention is made of the existence of the "Newer Pliocene" in North Carolina.

CONRAD, T. A.—*Observations on the Tertiary Strata of the Atlantic Coast.* Amer. Jour. Sci., vol. 28, pp. 104-111, 280-282, 1835.

The author discusses the Tertiary strata of the Atlantic Coast, and states that the Miocene is probably wanting. It seems that he would refer all of what we now call Miocene in North Carolina to the "Medial Pliocene," while his "Newer Pliocene" constitutes our Pleistocene. He gives a list of sixty-seven species of fossil shells from Mr. Benner's plantation on the Neuse River, below New Bern, only five of which are extinct or unknown. He refers the beds to the "Newer Pliocene." The lists of

fossils given seem to prove conclusively that they are Pleistocene. The writer compares the fossils from this locality with those found near the mouth of the Potomac River (Cornfield Harbor).

CROOM, H. B.—*Some Account of the Organic Remains Found in the Marl Pits of Lucas Benners, Esq., in Craven County, N. C.* Amer. Jour. Sci., vol. 27, pp. 168-171, 1835.

Mr. Benners' estate, where the pits were dug, was located on the north bank of the Neuse River, sixteen miles below New Bern. The pits were about 25 feet in depth, and about 10 feet below the surface of the river. The following genera are named and their measurements given:

1. *Pholas costata.*	7. *Arca.*	13. *Buccinum.*
2. *Venus.*	8. *Pecten.*	14. *Mya.*
3. *Strombus.*	9. *Ostrea.*	15. *Donax* (?).
4. *Murex.*	10. *Patella fornicata.*	16. *Nerita.*
5. *Cardium.*	11. *Pectunculus.*	17. *Madrepora porites.*
6. *Solen.*	12. *Conus.*	

Besides, there were sharks' teeth, vertebræ of fishes, and teeth, hoof, and horns of an elk, and grinder of *Mastodon giganteum.*

MORTON, SAMUEL G.—*Notice of the Fossil Teeth of Fishes of the United States, the Discovery of the Galt in Alabama, and a Proposed Division of the American Cretaceous Group.* Amer. Jour. Sci., vol. 28, 1835, pp. 276-278.

The author divides the American Cretaceous into the Upper division, the Medial division, and the Lower division. The beds included in the Upper division and at least a part of those included in the Lower division were later shown to belong to the Eocene.

1838.

CONRAD, T. A.—*Fossils of the Medial Tertiary of the United States.* No. 1, 1838, 32 pp., pls., 1-27, Phila. Republished by W. H. Dall, Washington, 1893.

Fossils are described from the Miocene at Murfreesborough, Wilmington, and near New Bern, which he refers to the "Medial Tertiary."

WAGNER, WILLIAM.—*Description of Five New Fossils of the Older Pliocene Formation of Maryland and North Carolina.* (Read, January, 1838.) Jour. Acad. Nat. Sci., Phila., vol. 8, 1838, pp. 51-53.

The three following new forms of Miocene shells from "Meherring River," North Carolina, are described and figured:

Pecten marylandicus,
Panopea goldfussii,
Mysia nucleiformis.

1840.

CONRAD, T. A.—*Fossils of the Medial Tertiary of the United States.* No. 2, 1840, pp. 33-56, pls. XVIII-XXIX. Phila. Published by W. H. Dall, Washington, 1893.

The following fossils are described:
Lucina divaricata, from Upper Tertiary of North Carolina.
Astarte lunulata, from Upper Tertiary, New Bern.
Pecten eboreus, from Upper Tertiary, New Bern.

CONRAD, T. A.—*New Fossil Shells from North Carolina.* Amer. Jour. Sci. and Arts, vol. 39, 1840, pp. 387-388.

The following new species of fossils from the "Medial Tertiary" of Duplin County are described:

Natica canrena,	*Fulgur contrarius,*	*Conus adversarius,*
Fulgur excavatus,	*Voluta carolinensis,*	*Lucina jamaicensis* Lam.

1841.

CONRAD, T. A.—*Description of Twenty-six New Species of Fossil Shells, Discovered in the Medial Tertiary Deposits of Calvert Cliffs, Maryland.* Proc. Acad. Nat. Sci., Phila., vol. 1, 1841, pp. 28-33.

The new species, *Astrea bella*, from near New Bern is described. The same description is repeated in the Jour. Acad. Nat. Sci., vol. 8.

CONRAD, T. A.—*Appendix to paper by* JAMES T. HODGE, *entitled, Observations on the Secondary and Tertiary Formations of the Southern Atlantic States.* Assoc. Amer. Geol., Trans., 1840-42; Appendix, 1843, pp. 106-111. Abstr., Amer. Jour. Sci., vol. 41, 1841, pp. 344-348.

See abstract of paper by Hodge.

HODGE, JAMES T.—*Observations on the Secondary and Tertiary Formations of the Southern Atlantic States, with an Appendix by* T. A. CONRAD. Abstract, Amer. Jour. Sci., vol. 41, pp. 182, 183, 332-348, 1841. Trans., Assoc. Amer. Geol., pp. 34-35, 94-111, 1843.

The occurrence of the "Secondary formation," consisting of a blue sandstone containing *Exogyra costata, Belemnites, Plagiostoma palagicum, Anomia ephippium,* etc., on the northeast banks of the Cape Fear River [doubtless meaning the Northeast Cape Fear River], in the neighborhood of South Washington [now Watha], is described. He thinks the occurrence of this rock between the Tertiary deposits to the east and west indicates a low anticlinal axis running north and south.

The shell marls at Murfreesboro, near Williamston, at the Natural Well in Duplin County, and at Wilmington, all of which are referred to the "Medial Tertiary," are described. A limestone is described from the western part of Jones County at the heads of Trent and New rivers, which contains 87% $CaCo_3$. This is referred to the "Secondary (Cretaceous) formation," but is undoubtedly Eocene. The Eocene at Wilmington seems also to have been confused with the Cretaceous.

A list of 84 species of "Medial Tertiary" (Miocene) fossils is given from the Natural Well and 52 from Wilmington. In the appendix 32 new species of fossils are described from the Natural Well and 18 are figured. Brief descriptions of Angola Bay and Holly Shelter Swamp, in Pender and Duplin counties, are given.

LIMBER, JOHN.—*Fossil Remains in Lenoir County, N. C.* Amer. Jour. Sci., vol. 40, p. 405, 1841.

In digging a ditch near the summit level between the Neuse and Northeast Cape Fear rivers, three miles from the Neuse and on a branch of it and at least 100 feet above the river, the following section was penetrated:

Fine white sand and vegetable matter............... 3 inches.
Shell bed .... 3 inches.
Yellowish clay containing bones of enormous size....few inches.
Black impervious clay, containing a few bones....depth unknown.

The shell marl is said to be very abundant and to have been used on the land.

REDFIELD, WILLIAM C.—*Fossil Shells from Tertiary Marl Beds at Washington, Beaufort County, N. C.* Amer. Jour. Sci., vol. 41, p. 161, 1841. Trans., Amer. Assoc. Geol., p. 14, 1843.

The fossils were said to occur at a depth of 15 to 20 feet below the surface and about 2 feet below the usual level of the water in Pamlico River and Sound. The fossils were in a good state of preservation and were supposed to belong to the Miocene period. No names of the species found are given.

1842.

CONRAD, T. A.—*Observations on a Portion of the Atlantic Tertiary Region, with a Description of New Species of Organic Remains.* Proc. Nat. Inst. Promotion of Science, vol. 1, pp. 171-194, 2 pls., 1842.

The thickness of the entire Miocene in the Atlantic Coastal Plain is given as 100 feet. It is said to occur in the eastern counties of North Carolina. The "Upper Tertiary," or post-Pliocene, with a thickness of 12 feet, is represented by the beds on the north side of the Neuse River. 15 miles below New Bern. A list of 34 species of mollusks is given. The locality is now considered Pleistocene.

CONRAD, T. A.—*Description of Twenty-four New Species of Fossil Shells, Chiefly from the Tertiary Deposits of Calvert Cliffs, Maryland* (read June 1, 1841). Jour. Acad. Nat. Sci., Phila., vol. 8, 1842, pp. 183-190.

Astrea bella, a new species of *Astrea* from near New Bern, is described.

HARLAN, R.—*Notice of Two New Fossil Mammals from Brunswick Canal, Georgia; with Observations on Some of the Fossil Quadrupeds of the United States.* Amer. Jour. Sci., vol. 43, 1842, pp. 141-144, 2 pls.

Mention is made of the teeth of a Sus from the post-Pliocene (Pleistocene) of New Bern, that was found in association with the remains of the mastodon, elephant, elk, deer, horse, seal, cetacea, tortoise, shark, skate snake, and fish, together with fossil shells. (These were probably from the Benners plantation, 15-16 miles below New Bern, on the north bank of the Neuse River.)

LYELL, CHARLES.—*On the Tertiary Formations and Their Connection with the Chalk in Virginia and Other Parts of the United States.* (Review of paper read before the Society.) Geol. Soc., London, Proc., vol. 3, 1842, p. 736.

The resemblance of the marls on Northeast Cape Fear River near South Washington to the New Jersey Cretaceous marls, both as regards lithology and organic content, is noted. This locality was first reported by Mitchell, and later the materials were referred to the "Secondary formation" by Hodge. He states that these marls extend to the south of Lewis Creek along the Northeast Cape Fear nearly to Rocky Point, where they are covered by the Eocene limestone and conglomerate. He could find no

organic remains which supported the view held by Hodge and other geologists, that the latter was an "upper Secondary" deposit or a deposit interposed between the Cretaceous and the Eocene.

MITCHELL, ELISHA.—*Elements of Geology, with an Outline of the Geology of North Carolina.* 1842, 141 pp. (esp. pp. 123-141).

Geologic map of State under first cover. He divides the Coastal Plain materials into two classes, namely, the Tertiary strata and the "Secondary" strata. He does not clearly differentiate between the Tertiary and later deposits. The character of the materials which go to make up the land of the low country and the age of the fossil remains which they contain are briefly described.

A formation contemporaneous with the marls of New Jersey and the Cretaceous of Europe is described as underlying the southern part of the State, outcropping at intervals from the eastern part of Jones County to the Cape Fear River. He states that it is well exhibited at Wilmington, and the good lands of Jones and Onslow counties and those at Rocky Point in Pender County are ascribed to it. The rocks to which he refers are the well-known Eocene limestone of this region, which up to this time had been regarded by Mitchell and other geologists as of "Secondary" age. No definite mention is made of the greensands of the Cape Fear River.

1843.

CONRAD, T. A.—*Description of a New Genus, and Twenty-nine New Miocene and One Eocene Fossil Shells of the United States.* Proc. Acad. Nat. Sci., Phila., vol. 1, 1843, pp. 305-311.

The following new species of Miocene shells from North Carolina are described:

Miocene	*Carditamera carinata*	New Bern.
	Pecten vicenarius	Wilmington.
	Amphidesma æquata	Wilmington.
	Lucina multistriata	Wilmington.
	Oliva duplicata	Wilmington.
	Venus cribraria	Wilmington and Neuse River below New Bern.
	Crepidula densata	Natural Well, Duplin County.
	Tellina arctata	North Carolina.

RUFFIN, EDMUND.—*Report of the Commencement and Progress of the Agricultural Survey of South Carolina.* Columbia, S. C., 1843, 120 pp. (esp. pp. 7, 24-27).

Describes the lithologic character, stratigraphic position and distribution of the "Secondary" or Peedee formation. This terrane corresponds to Sloan's "Burches Ferry marl" (1907). He also describes a "shale" or clay underlying the Peedee ("Burches Ferry") formation, which he does not name, but which corresponds to Sloan's Black Creek shale (1907).

1844.

LYELL, CHARLES.—*On the Geological Position of the Mastodon Giganteum and Associated Fossil Remains at Bigbone Lick, Kentucky, and Other Localities in the United States and Canada.* Amer. Jour. Sci., 1st series, vol. 46, 1844, pp. 320-323.

Notes the occurrence of a large assemblage of mammalian bones, including those of the mastodon giganteum, on the Neuse River 15 miles below New Bern.

LYELL, CHARLES.—*Notes on the Cretaceous Strata of New Jersey and Parts of the United States Bordering the Atlantic.* Amer. Jour. Sci., vol. 47, 1844, pp. 213-214.

Describes the Cretaceous of the Atlantic Coast of the United States as consisting of greensand and marl, red and highly ferruginous sandstones, white sand, limestone, and some beds of lignite. He states that they agree in their lithologic characters with the Lower Cretaceous series of Europe, but that in their fossils they agree far more nearly with the European strata ranging from the Gault to the Mæstricht beds inclusive.

At South Washington (now Watha), Pender County, North Carolina, he found Cretaceous strata with characteristic Cretaceous fossils, some common to the lower and some to the upper fossiliferous group of New Jersey. He also found several new species. The pebbly limestone at Wilmington is referred to the Eocene.

RUFFIN, EDMUND.—*Secondary and Miocene Marls on and Near Lynch's Creek, in Darlington, Sumter, Williamsburgh, and Marion Districts.* (Supplemental report of the agricultural survey for 1843.) Report on the Geological and Agricultural Survey of the State of South Carolina, Columbia, S. C., 1844, pp. 59-63.

Describes occurrence of the "Secondary formation" on Lynch's Creek in South Carolina and on the Waccamaw River in the vicinity of Conway. He also gives an account of two exposures of "Secondary" marl which he observed near South Washington, North Carolina, from which he obtained *Belemnitella, Exogyra lastatæ* [probably meaning *costata*], and large thick shells of a similar oyster. This was doubtless the same, or approximately the same, horizon at which Lyell made his collection.

1845.

BAILEY, J. W.—*Notice of Some New Localities of Infusoria, Fossil and Recent.* Amer. Jour. Sci., vol. 48, 1845, pp. 321-343, pl. IV.

Mention is made of the presence of fossil *Polythalamia* in the Miocene marl at Wilmington, N. C.

CONRAD, T. A.—*Fossils of the (Medial Tertiary or) Miocene Formation of the United States.* No. 3, 1845, pp. 57-80, pls. XXX-XLV, Philadelphia. Republished by W. H. Dall, Washington, 1893.

A large number of fossils are described from the Neuse River near New Bern, from Wilmington, and from the Natural well in Duplin County.

FORBES, EDWARD.—*On the Fossil Shells Collected by Mr. Lyell from the Cretaceous Formations of New Jersey.* Geol. Soc., London, Quart. Jour., vol. 1, 1845, pp. 61-62.

Describes and figures the new species, *Ostrea subspatulata*, from Lewis Creek near South Washington, N. C., collected by Lyell.

LYELL, CHARLES.—*Travels in North America, with Geological Observations on the United States, Canada, and Nova Scotia.* 2 vols.: vol. 1, 251 pp.; vol. 2, 221 pp., 7 pls. 12 mo. New York, 1845. Other editions published in London and Halle.

The occurrence of Cretaceous greensand marl on Lewis Creek near South Washington is described, and the presence of *Belemnitella* and other characteristic New Jersey Cretaceous forms is noted (vol. 1, p. 156).

Reference is made to the fossil beds on the lower Neuse River previously described by Conrad, and the presence of fossiliferous strata of Eocene and Miocene age at Wilmington. He also describes the general character of the great Dismal Swamp and the pine barrens of Virginia and North Carolina.

LYELL, CHARLES.—*Observations on the White Limestone and Other Eocene or Older Tertiary Formations of Virginia, South Carolina, and Georgia.* Quar. Jour. Geol. Soc., vol. 1, pp. 429-442, 1845.

The writer notes the differences between the Eocene of Maryland and Virginia, in which greensand predominates, and the Eocene of the Carolinas and Georgia, where the materials consist principally of highly calcareous white marls and white limestones. The Eocene exposures at Wilmington and Rocky Point on the Northeast Cape Fear River are briefly described. At Wilmington he collected 39 species of fossils, most of which are determined generically only. *Terebratula wilmingtonensis* is described as a new species. In conclusion, he states that there are few Eocene species common to the United States and Europe, and only one from the Wilmington Eocene, *Infundibulum trochiforme.*

LYELL, CHARLES.—*On the Miocene Tertiary Strata of Maryland, Virginia, and of North and South Carolina.* Quar. Jour. Geol. Soc., vol. 1, pp. 413-429, 1845.

"In the cliffs at Wilmington, North Carolina, resting on a calcareous eocene rock, are seen miocene shelly strata of the ordinary character, in which I collected about thirty species of shells" (p. 418). The following recent species were found there in the Miocene: *Calyptraea costata, Dentalium dentalis, Solen ensis, Lucina anodonta, Lucina contracta,* and *Venus mercenaria. Lucina contracta* also occurs in the Suffolk Crag, while several of the Wilmington forms are said to be very closely allied to European Miocene species.

LYELL, CHARLES.—*Notes on the Cretaceous Strata of New Jersey, and Other Parts of the United States Bordering the Atlantic.* Geol. Soc., London, Quart. Jour., vol. 1, 1845, pp. 55-60.

The Lewis Creek locality near South Washington (now Watha) is correlated with the Cretaceous strata of New Jersey. A partial list of the fossils is given.

1848.

TUOMEY, MICHAEL.—*Reports on the Geology of South Carolina.* Columbia, S. C., 1848. 293 pp., 2 maps (esp. pp. 132-139). Review Amer. Jour. Sci., 2d series, vol. 8, 1849, pp. 61-74.

In this report (pp. 132-139) Professor Tuomey describes in detail the localities at which he observed Cretaceous strata. These are limited to the eastern part of the State, occurring principally in the banks and bluffs of the Peedee, Waccamaw, and Black rivers and their tributaries. He states that these beds form a continuation of the Cretaceous strata outcropping on the Cape Fear River in North Carolina. The latter are said to contain a small content of glauconite, but not a grain did he observe in the former. A list of the Cretaceous fossils is given.

1852.

DESOR, E.—*Post-Pliocene of the Southern States and its Relation to the Laurentian of the North and the Deposits of the Valley of the Mississippi.* Amer. Jour. Sci., 2d series, vol. 14, 1852, pp. 49-59.

The beds along the Neuse River below New Bern, evidently those on Benners' plantation, described by Conrad, are referred to the post-Pliocene.

EMMONS, EBENEZER.—*Report of Professor Emmons on His Geological Survey of North Carolina*, pp. 3-182. Raleigh, 1852.

The greensand occurring on Cape Fear River, at various localities below Elizabethtown and at Wilmington, which he regards as of higher value as a fertilizer than the shell marl of the region, he correctly refers to the Cretaceous.

Many analyses of soils and marls are given, and various sections of the marl beds described. The fossiliferous beds containing oysters and clams primarily in the vicinity of the ocean are referred to the post-Pliocene; certain beds near New Bern, and probably some deposits along Fishing Creek, to the Pliocene; to the Miocene are referred the beds near Goldsboro, Tarboro, Rocky Mount, along the Toisnot and Contentnea creeks, the Neuse and Tar rivers; at Elizabethtown, Walker's Bluff, and Brown's Landing; to the Eocene certain gravel beds in the vicinity of Leaksville, Rockingham County, and Carthage, Moore County (these are probably Cretaceous), and greenish-colored clays and marls found at Colonel Collier's plantation, near Goldsboro, and at Wilmington.

McLENAHAN, S.—*Letter to Professor Emmons, State Geologist, in Report of Geological Survey of North Carolina*, pp. 168-173. Raleigh, 1852.

He reports the presence of a siliceous, shelly limestone (Eocene) ten miles southeast of Raleigh, and describes the skeleton of a whale found in the marl of Fishing Creek.

1853.

CONRAD, T. A.—*Monograph of the Genus Fulgur.* Proc. Acad. Nat. Sci., Phila., vol. 6, 1853, pp. 316-19.

The following forms are recorded from the Natural well, Duplin County:

Fulgur canaliculatum,
Fulgur contrarium,
Fulgur excavatum.

Fulgur carica is reported from North Carolina, but the exact locality is not given.

MARCOU, JULES.—*A Geological Map of the United States, and the British Provinces of North America; with an Explanatory Text, Geological Sections, etc.* 1853, pp. 48-57. (Geological map in separate cover.)

Describes the character and distribution of the Quaternary deposits of the Atlantic Coastal Plain. On the accompanying geological map the Quaternary and Tertiary deposits are represented by one color.

1854.

TUOMEY, M.—*Description of Some Fossil Shells from the Tertiary of the Southern States.* Proc. Phila. Acad. Nat. Sci., vol. 6, pp. 192-194, 1852; vol. 7, p. 167, 1854.

Discusses the presence of Cretaceous fossils in the Eocene strata at Wilmington and says that they lived during the Eocene and were not redeposited by the breaking up of Cretaceous strata. His reason for such a view is that the internal casts of both Cretaceous and Eocene forms consist of compact white limestone unlike any materials formed in the Cretaceous of North Carolina. He describes the following forms from the beds at Wilmington:

Trochus nixus,	*Voluta conoides,*	*Cardita trapezium,*
Pyrula ampla,	*Trigonia lunata,*	*Arca cancellata,*
Fusus abruptus,	*Trigonia divaricata,*	*Cucullæ lævis.*
Conus mutilatus,		

1856.

EMMONS, EBENEZER.—*Geological Report of the Midland Counties of North Carolina.* New York and Raleigh, 1856, 351 pp.

Divides the State into three natural belts or zones, the Eastern, Western, and Midland. The character and extent of the Eastern zone [Coastal Plain] is briefly indicated (p. 3).

1857.

FOSTER, J. W.—*On the Geological Position of the Deposits in Which Occur the Remains of the Fossil Elephant of North America.* Proc. Amer. Assoc. Adv. Sci., vol. 10, Pt. II, pp. 148-167. 1857.

Reference is made to the Pleistocene deposits on the Neuse River below New Bern containing remains of the mastodon, elephant, hippopotamus, horse, deer, and elk, that Conrad described in 1835. The age is regarded as upper Tertiary.

1858.

EMMONS, EBENEZER.—*Report of the North Carolina Geological Survey. Agriculture of the Eastern Counties.* xvi, 314 pp. Raleigh, 1858.

This report contains good descriptions of the marl beds of the Cretaceous, Eocene, and Miocene formations of the State, together with many analyses. Many sections are given. For the most part those deposits containing marine shells are referred to their proper series, but the Cretaceous lignitic sands and clays occurring on Cape Fear River from

a dozen or more miles below Elizabethtown upstream nearly to Fayetteville are regarded as of probable Eocene age. The occurrence of *Belemnitella*, *Exogyra*, and coprolites as a mechanical mixture in the Miocene marl is mentioned. The report contains an extended account of the fossils of the marl beds, of which over 200 species, many of which are new, are described and figured. It is the most complete report on the Coastal Plain formations of the State published, up to that time. The soils of various Coastal Plain counties are described.

1860.

EMMONS, EBENEZER.—*North Carolina Geological Survey, Part II, Agriculture.* Raleigh, 1860, 95 pp.

Describes the geographic distribution and character of the swamp lands, with special reference to the nature of the soils, of which many analyses are given. He regards the swamp accumulations as of recent origin.

1861.

CONRAD, T. A.—*Fossils of the (Medial Tertiary or) Miocene Formation of the United States.* No. 4, 1861 (?), Phila., pp. 81-89, index and plates xlv-xlix. Republished by W. H. Dall, Washington, 1893.

Crypta densata,
Busycon contrarium,
Fasciolaria rhomboidea,

are described from the Natural well in Duplin County.

RUFFIN, EDMUND.—*Sketches of Lower North Carolina and the Similar Adjacent Lands*, 296 pp. Printed at the Institution for the Deaf, Dumb, and the Blind, Raleigh, 1861.

Contains general statements in regard to the marl deposits of the State. The deposits are said to belong to the Tertiary, though no mention is made of the different divisions. To explain the origin of the materials of the "drift region" (Coastal Plain), he adopts the already antiquated theory of H. H. Hayden which appeared in his "Geological Essays" published in 1820.

1864.

CONRAD, T. A.—*Notes on Shells, with Description of New Fossil Genera and Species.* Proc. Acad. Nat. Sci., Phila., vol. 16, 1864, pp. 211-214.

The new species of *Fasciolaria subtenta* is described from the Natural well in Duplin County.

1865.

CONRAD, T. A.—*Observations on the Eocene Lignite Formation of the United States.* Proc. Phila. Acad. Sci., vol. 17, pp. 70-73, 1865. Amer. Jour. Sci., 2d series, vol. 40, pp. 265-268, 1865.

In this article it is stated for the first time that the commingling of Cretaceous and Eocene fossils in the limestone breccia at Wilmington was due to mechanical mixture. It is explained as due to a "disturbance in the bed of the Eocene ocean."

1867.

CONRAD, T. A.—*Tertiary of North and South Carolina.* Amer. Jour. Sci., 2d series, vol. 43, p. 260, 1867.

The author refers to the presence of Cretaceous fossils in the Eocene strata at Wilmington and in the Miocene strata of the Cape Fear River, and considers the mixture of forms as purely accidental and not due to the coexistence of Cretaceous forms with Eocene and Miocene forms during the two latter periods.

1869.

KERR, W. C.—*Report of the Progress of the Geological Survey of North Carolina.* 57 pp., Raleigh, 1869.

The statement is made (p. 10) that the marls along "the lower waters of Cape Fear, Northeast, Trent, Neuse, and Tar rivers" have been examined in search of phosphatic materials similar to the phosphates of Charleston, but with negative results.

1870.

MARSH, O. C.—*Notice of Some Fossil Birds, from the Cretaceous and Tertiary Formations of the United States.* Amer. Jour. Sci., 2d series, vol. 49, 1870, pp. 205-217.

The left humerus of a bird which was found at Tarboro is described by the writer and referred to the new species, *Catarractes antiquus.* It is supposed to have come from the Tertiary of that region. The same specimen is mentioned on p. 237 of the Proceedings of the Academy of Natural Sciences of Philadelphia for 1866.

1871.

CONRAD, T. A.—*On Some Points Connected with the Cretaceous and Tertiary of North Carolina.* (From a letter to J. D. Dana, dated Greenville, Pitt County, N. C., 1871.) Amer. Jour. Sci., 3d series, vol. 1, pp. 468-469, 1871.

In the vicinity of Greenville the Miocene is said to rest directly upon Cretaceous strata in which occur Ripley fossils.

He reports finding a tooth which he thinks belongs to Leidy's *Equus fraternus* and a *Mastodon* jaw, both of which he believes to have come from the Miocene.

Reference is also made to the occurrence of Ripley fossils at Snow Hill in Greene County. This is probably the first recorded attempt at correlating North Carolina Cretaceous strata with the Ripley in the Gulf region.

KERR, W. C.—*On Some Points in the Stratigraphy and Surface Geology of North Carolina.* Amer. Nat., vol. 4, 1870-71, p. 570.

Gives evidence indicating considerable oscillations of sea-level during the pre-human period. States that these movements were probably synchronous with the "Champlain" epoch.

PERRY, JOHN B.—*Remarks on Southern Drift, Gulf Tertiary, and Notices of Occurrence of Cretaceous at Snow Hill in North Carolina.* In discussion of E. W. Hilgard, The History of the Gulf of Mexico. Amer. Assoc. Adv. Sci., 1871. Amer. Nat., vol. 5, 1871, pp. 521-522.

Contains a brief reference to a Cretaceous fossil locality at Snow Hill, North Carolina.

1872.

ELLIOTT, GEO. H.—*Report on the Survey of the Cape Fear and Deep Rivers, North Carolina.* Report of the Chief of Engineers, 1872, pp. 741-749.

Gives a brief description of the region through which the Cape Fear River flows.

SHALER, N. S.—*On the Causes Which Have Led to the Production of Cape Hatteras.* Proc. Boston Soc. Nat. Hist., vol. 14, pp. 110-121, 1872. Abstract, Amer. Nat., vol. 5, pp. 178-181, 1871.

The view is expressed that the Cape Hatteras projection was caused by the operation of subterranean forces which resulted in the uplift of the region. In support of this view he states that there is evidence that a ridge once existed along a line passing north and south through Richmond, Va., and Weldon, N. C., which was produced by an upward folding of the rocks. This ridge was subsequently much eroded and finally covered by later deposits. This uplift probably occurred subsequent to the beginning of the Tertiary, or there may have been a succession of uplifts. Professor Shaler appears to have regarded Cape Hatteras as a southeasterly continuation of this ridge.

Brief descriptions of some of the Tertiary deposits of North Carolina are given. "Along the shore of the mainland from New Bern, N. C., to Washington, at the mouth of the Roanoke, the hard, shelly limestone of the Tertiary period, looking much like the shell bed which is found near Charleston, S. C., comes to the surface just above high-tide mark and seems to be the principal barrier to the encroachment of the sea" (p. 117).

1873.

KERR, W. C.—*Topography as Affected by the Rotation of the Earth.* Amer. Phil. Soc., Proc., vol. 13, 1873, pp. 190-192.

Notes the fact that the high bluffs of the North Carolina rivers are, in most cases, on the right side, and assigns as the cause the deflecting effect of the rotation of the earth on the courses of the streams.

KERR, W. C.—*Appendix to the Report of the Geological Survey of North Carolina, 1873,* being a brief abstract of that report and a general description of the State—geographical, geological, climatic, and agricultural. 24 pp., map. Raleigh, 1873.

"The Tertiary (and Quaternary) occupies the eastern champaign section, and consists mainly of beds of uncompacted clays, sands, and marls, belonging to the lower and middle divisions (Eocene and Miocene), which are everywhere filled with exuviæ and bones of marine animals, constituting an inexhaustible resource of manurial matter" (p. 6).

"Marl is found only in the eastern region, but is very abundant in some 25 counties, occurring in extensive superficial beds, which contain all the elements of a complete and permanent fertilizer. * * * This is the most valuable mineral in the State, as it is easily accessible to more than half of the farming lands, and is applicable to all crops."

1875.

CONRAD, T. A.—*Descriptions of New Genera and Species of Fossil Shells of North Carolina and in the Cabinet at Raleigh, etc.* Geol. Survey of North Carolina, Report by W. C. Kerr, Appendix A, pp. 1-28, pls. 1-4. Raleigh, 1875.

Describes 46 new species of Cretaceous shells from Snow Hill, and states that they represent the Ripley of Mississippi. A synopsis of the Cretaceous Mollusca of North Carolina is given.

Three new species of Eocene fossils and 22 new species of Miocene shells are described and figured. Conrad believes that all the Tertiary strata of North Carolina should be referred to the Eocene and Miocene.

COPE, EDWARD D.—*Synopsis of the Vertebrata whose Remains Have Been Preserved in the Formations of North Carolina.* Geol. Survey North Carolina, Report by W. C. Kerr, vol. 1, Appendix B, pp. 29-52, pls. 5-8. Raleigh, 1875.

A number of new fossil vertebrates are described from the Miocene deposits of the State.

GENTH, F. A.—*On the Minerals Found in the State of North Carolina.* Geol. Survey North Carolina, Report by W. C. Kerr, vol. 1, Appendix C, pp. 53-69. Raleigh, 1875.

A few minerals, calcite, quartz, glauconite, etc., are reported to occur in the Tertiary marl beds.

KERR, W. C.—*Report of the Geological Survey of North Carolina.* Vol. 1, 8vo, xviii, 325 pp. Appendices, 120 pp., 8 pl., 18 figs. Geological map of State under front cover. Raleigh, 1875.

In the preface the following statement is made: "This volume may be considered, in part, as a sort of résumé of the whole subject of the geology of the State, as far as worked out, the labors of my predecessors being freely used and embodied with my own."

The character and geographic distribution of the Cretaceous and Tertiary deposits of the State are described. The Tertiary deposits are divided into the Eocene and the Miocene, and the geographic limits of each are given. The marls of the Cretaceous, Eocene, and Miocene are described in detail. Many analyses are given, and the value of these marls for fertilizing purposes is fully discussed.

The surficial deposits, consisting of beds of pebbles, sand, and clay, are included in the Quaternary system. He believes that the Coastal Plain region was submerged during at least a part of the glacial period, and regards the Quaternary deposits as having been transported by the great floods resulting from the melting of the ice of the glacial period. The report is accompanied by a geological map of the State.

1876.

ABERT, S. T.—*Geology.* Letter from the Acting Secretary of War, transmitting report of S. T. Abert on the survey of a line to connect the waters of the Cape Fear and Neuse rivers, etc. Sen. Ex. Doc., No. 35, 44th Cong., 1st Sess., pp. 15-24, 1876.

Describes the physical features of the seacoast and of the sounds bordering the coast. Describes briefly the geology of the region between Nor-

folk and Cape Fear River. Brief statements are made concerning the Eocene and Miocene formations of the Coastal Plain. Describes rivers, peat-bogs, swamps and soils.

GABB, WILLIAM.—*Notes on American Cretaceous Fossils, with Descriptions of Some New Species.* Acad. Nat. Sci., Proc., Phila., 1876, pp. 276-324.

Describes, among other Cretaceous fossils, a few species from North Carolina.

1879.

KERR, W. C.—*Physiographic Description of North Carolina.* North Carolina Geological Survey, 1879, 32 pp. and map and section under back cover.

Describes briefly the physiographic features of the eastern section (Coastal Plain), pp. 6-7. On the map the swamp lands in the region bordering the coast are indicated.

KERR, W. C.—North (and South) Carolina (geological formations). Macfarlane's American Railway Guide, p. 186, 1879.

Contains very brief statements concerning the geology along the various railroads.

1881.

GENTH, F. A., and KERR, W. C.—*Mineralogy: Minerals and Mineral Localities of North Carolina,* being Chapter 1 of the 2d volume of the Geology of North Carolina, pp. 1-122. Raleigh, 1881.

Calcite, siderite, limonite, glauconite, pyrite, lignite, and vivianite are reported from Cretaceous and Tertiary deposits in several of the Coastal Plain counties of the State.

1883.

HEILPRIN, ANGELO.—*On the Relative Ages and Classification of the Post-Eocene Tertiary Deposits of the Atlantic Slope.* Proc. Phila. Acad. Nat. Sci., vol. 34, pp. 150-186, 1882.

In an examination of the post-Eocene fossils of the Atlantic Coastal Plain, the writer finds that of about 206 North Carolina mollusca, 128 are found in South Carolina, 79 in Virginia, 54 in Maryland, while 54 are recent. He, therefore, concludes that these deposits in North and South Carolina constitute the highest group of the Miocene strata, to which he applies the name "Carolinian," while the Miocene deposits of Virginia and Maryland are referred to the middle Miocene, or "Virginian," and the lower Miocene or "Marylandian."

KERR, W. C.—*Report on the Geology and the Soils of the Tobacco Region of North Carolina.* Tenth Census United States, vol. 3, 1883, pp. 715-19 (bottom pagination).

States that the soils of the champaign or eastern tobacco district are formed of Quaternary deposits. The character and stratigraphic relations of these deposits are briefly described.

1884.

HEILPRIN, ANGELO.—*The Tertiary Geology of the Eastern and Southern United States.* Jour. Phila. Acad. Nat. Sci., vol. 9, Pt. I, pp. 115-154, map 4, 1884.

General descriptions are given of the Eocene and Miocene. Much is quoted from Kerr's Report on the Geology of North Carolina, 1875. A list of 26 species of Eocene fossils from the State is given.

HEILPRIN, ANGELO.—*Contributions to the Tertiary Geology and Paleontology of the United States.* 117 pp., map, 4to. Philadelphia, 1884.

The writer gives little new information in regard to the Eocene, but does give a short summary of existing information concerning the Eocene strata and their contained fossils. He does not attempt to correlate them with Eocene strata elsewhere in the United States.

The Miocene is discussed at considerable length, and from a comparison of the fossils he comes to the conclusion that these strata represent the same formation in North and South Carolina, and that they are younger than the Miocene deposits of Virginia and Maryland. The name "Carolinian" is applied to them.

KERR, W. C.—*The Geology of Hatteras and the Neighboring Coast.* (Abstract.) Bull. Wash. Phila. Soc., vol. 6, pp. 28-30, 1884. Abstract, Science, vol. 1, p. 402, 1883.

Describes in a general way the character of the low-lying region adjacent to Cape Hatteras.

The statement is made that "the quaternary as well as the tertiary of this coast region of North Carolina are laid down upon an eroded surface of cretaceous rock."

PHILLIPS, W. B.—*North Carolina Phosphates.* Jour. Elisha Mitchell Sci. Soc., 1883-1884, pp. 60-63. Abstract, Amer. Jour. Sci., 3d series, vol. 28, p. 75.

The phosphatic materials found in the Miocene strata of Duplin, Brunswick, and Pender counties are described. The best localities are said to be from 4 to 8 miles northeast of Magnolia, where a thin irregular bed of phosphate is found in places at a depth of from 3 to 5 feet beneath the surface.

1885.

HOLMES, J. A.—*Taxodium (Cypress) in North Carolina Quaternary.* Elisha Mitchell Sci. Soc. Jour., 1884-85, pp. 92-93, 1885.

Describes the occurrence of fossil stumps of cypress on the southwest bank of the Neuse River 10 to 12 miles below the town of New Bern.

KERR, W. C.—*The Eocene of North Carolina.* Amer. Nat., vol. 19, p. 69, 1885.

Through finding upper Eocene fossiliferous rocks capping some of the highest hills of the Coastal Plain, the author concludes, erroneously, that most of the sand and gravel deposits, previously referred to the Quaternary, are really Eocene in age. "The area of Tertiaries in this State must now be extended over a wide stretch of country, from the tops of Laurentian hills, near Raleigh, and the higher elevations of the Huronian slates, to from 50 to 75 miles southeastward, along the course of the Deep River, and so onward to the South Carolina border, reaching at one point an elevation of 600 feet above tide. This leaves the Quaternary, like the Miocene, to be represented by a thin and broken covering of superficial deposits, of only a few feet to a few yards in thickness, and reaching from the coast only about 100 miles inland and an elevation but little above 100 feet."

KERR, W. C.—*Distribution and Character of the Eocene Deposits in Eastern North Carolina.* Elisha Mitchell Sci. Soc. Jour., for the year 1884-1885, pp. 79-84.

Essentially the same discussion as in the preceding paper.

1888.

HEILPRIN, ANGELO.—*The Classification of the Post-Cretaceous Deposits.* Proc. Phila. Acad. Nat. Sci., 1887, pp. 314-322, 1888.

The author again refers to the Miocene of the Atlantic Coastal Plain as consisting of the three divisions: "Marylandian," "Virginian," and "Carolinian."

McGEE, W J—*Three Formations of the Middle Atlantic Slope.* Amer. Jour. Sci., 3d series, vol. 35, 1888. *Potomac Formation*, pp. 120-143. *Appomattox Formation*, pp. 328-330. *Columbia Formation*, pp. 367-388, 348-366.

Materials exposed on Roanoke River near Weldon, which he regards as representing the Potomac formation of Virginia, are described (p. 126). This is the only reference to Potomac equivalents in North Carolina.

Concerning the presence of the "Appomattox" formation in North Carolina he says: "And at Weldon it rests upon deeply ravined crystalline rocks, save where inconspicuous remnants of Potomac arkose intervene" (p. 330). The formation is said to be the equivalent of at least a part of the "Orange Sand" of Hilgard. As regards the age of the formation, he states that "It is manifestly newer than the fossiliferous Miocene upon which it rests, and older than the Columbia formation by which it is overlain" (p. 330).

The Columbia formation is divided into the *Fluvial Phase* and the *Interfluvial Phase.* Both phases are mentioned as occurring along the Roanoke River in North Carolina. Terracing is mentioned as occurring along Roanoke River in the vicinity of Weldon.

PENROSE, R. A. F., JR.—*Nature and Origin of Deposits of Phosphate of Lime,* with an introduction by N. S. Shaler. Bull. U. S. Geol. Surv., No. 46, 143 pp., 3 pls. Washington, 1888.

Brief descriptions with chemical analyses are given of the character and occurrence of amorphous nodular phosphates in North Carolina. They occur in Duplin, Sampson, Onslow, Pender, New Hanover, and Columbus counties. The most valuable deposits occur at Castle Hayne and near Wilmington, and these are briefly described (pp. 70-75).

1889.

FONTAINE, WM. M.—*The Potomac or Younger Mesozoic Flora.* U. S. Geol. Survey, Monograph XV, 2 vols., 1889. Text 377 pages.

Describes the deposit of supposed Potomac at Weldon as consisting of a thin layer of sands and gravels resting directly upon the crystalline rocks. He believes it referable to the Potomac upon lithologic grounds. He says: "It suggests the idea that the Potomac may be found as far south as this place. The exposure, however, is too slight to be taken as anything more than suggestive of probabilities" (pp. 45-46).

HOLMES, J. A.—*Historical Notes Concerning the North Carolina Geological Surveys.* Elisha Mitchell Sci. Soc. Jour., vol. 6, Pt. I, January-June, 1889, pp. 5-19.

Gives a brief account of the several North Carolina State surveys that have been called geological surveys, including lists of publications.

1890.

CHANCE, H. M.—*North Carolina (Geological Formations).* Macfarlane's Geol. Ry. Guide, 2d edition, pp. 365-368, 1890.

The "Sketch of the Geology and Topography of North Carolina" contained in this work is abstracted from the geological reports of Prof. W. C. Kerr. The references to the Mesozoic and Cenozoic strata are very brief.

CLARK, W. B.—*On the Tertiary Deposits of the Cape Fear River Region.* Bull. Geol. Soc. Amer., vol. 1, pp. 537-540, 1890.

He shows that the Cretaceous greensand marl occupies the base of the series in the lower Cape Fear River region. The commingling of Eocene and Cretaceous forms at Wilmington is discussed and is explained as due to a reworking of the Cretaceous forms during the Eocene. The following Eocene forms are given:

Aturia alabamiensis Conrad.
Conus gyratus Conrad.
Emarginula eversa Conrad.
Lunulites distans Lonsdale.
Mortonia pileus-sinensis Ravenel.
Oliva alabamiensis Conrad.
Pecten membranosus Morton.
Pseudoliva vetusta Conrad.
Siliquaria vitis Conrad.
Sismondia plana Conrad.
Terebratulina lachryma Morton.
Trochita trochiformis Conrad.

In the same bed the following Cretaceous fossils occur:

Baculites compressus Say.
Cardium spillmani Conrad.
Cucullæa antrosa Morton.
Gyrodes abyssina Conrad.
Nautilus dekayi Morton.
Navicula uniopsis Conrad.
Venilia conradi (?) Morton.
Zenophora leprosa Morton.

DALL, WILLIAM HEALEY.—*Contributions to the Tertiary Fauna of Florida, with especial reference to the Miocene Silex Beds of the Caloosahatchie River, including, in many cases, a complete revision of the generic groups treated and their American Tertiary species.* Trans., Wagner Free Institute of Science of Phila., vol. 3, 1654 pp., 60 pls. Pt. I, 1890; Pt. II, 1892; Pt. III, 1895; Pt. IV, 1898; Pt. V, 1900; Pt. VI, 1903.

In this exhaustive work a great number of fossils are described from the Tertiaries of North Carolina. The most important contributions are with reference to the Miocene deposits of Duplin County, which are regarded as closely related to the beds at Yorktown, Va. This correlation was established after a very detailed study of the fossils had been made. The deposits in the vicinity of Croatan are placed in the Pliocene as

the result of a careful study of the contained fossils. Eighty out of ninety-six recognized species are represented in the recent fauna; 83 per cent of which, according to Lyell's original classification, would place these beds unquestionably in the Pliocene.

FONTAINE, WILLIAM M.—*Potomac Strata at Haywood, Chatham County, N. C.* U. S. Geol. Survey, 10th Ann. Rpt. (1888-1889), 1890, p. 174.

Announces the discovery of supposed Potomac strata near Haywood, N. C.

MCGEE, W J—*Southern Extension of the Appomattox Formation.* Amer. Jour. Sci., 3d ser., vol. 40. 1890, pp. 15-41.

Deposits referable to this formation are said to occur throughout the extent of the Atlantic and Gulf Coastal Plains as far as the Rio Grande. In North Carolina it forms a terrane 40 or 50 miles wide on the Roanoke and extends southward through the Carolinas in a broad zone. In Virginia and the Carolinas the deposits are said to lie at elevations of between 25 and 250 feet above tide. As regards its age, the formation is said to correspond roughly with the Pliocene.

SHALER, N. S.—*General Account of the Fresh-water Morasses of the United States, with a Description of the Dismal Swamp District of Virginia and North Carolina.* U. S. Geol. Surv., 10th Report, pp. 255-339, pls. 6-19, Washington, 1890.

Describes the Dismal Swamp district (pp. 313-339) as regards the character of the materials, the topographic features, the character of the animal and vegetable remains, etc. On the evidence of some fossils found near Suffolk, Va., the writer believes that the entire district is underlain by Pliocene strata.

An escarpment is described which forms the western boundary of the district, and which is believed to mark a former shore line. This is called the Nansemond Escarpment. A higher plain of which this escarpment forms the eastern boundary is designated the Nansemond Bench.

1891.

CLARK, WILLIAM BULLOCK.—*Correlation Papers—Eocene.* U. S. Geol. Surv., Bull. 83, 173 pp., 2 maps. Washington, 1891.

This paper contains a discussion of the previously published literature pertaining to the Eocene of the United States together with a correlation of the Eocene deposits in the several areas.

MCGEE, W J—*The Lafayette Formation.* U. S. Geol. Surv., 12th Ann. Rept., 1890-91, Pt. I, pp. 347-521.

The author presents a monographic study of the Lafayette formation in the eastern United States.

The term Lafayette is here used instead of "Appomattox," which was the original designation of the formation. As to age, the formation is regarded as late Neocene. The character, distribution, and stratigraphic position of the formation in North Carolina are described.

STANTON, T. W.—*Cretaceous and Tertiary Strata Near Wilmington, N. C.* Amer. Geol., vol. 7, pp. 333-334, 1891.

The Eocene exposures at Wilmington, Castle Hayne, and Rocky Point are briefly described. There the formation rests upon the Cretaceous, and fossils from the latter are found redeposited in the Eocene strata mingled with Eocene fossils. The Cretaceous forms present in the Eocene deposit at Castle Hayne are as follows:

Cardium eufaulense Con.
Exogyra costata Say.
Aphrodina tippana Con.
Cucullæa antrosa Mort.
Pachycardium spillmani Con.
Ostrea subspatulata L. and S.
Crassatella pteropsis Con.
Trigonia divaricata Tuomey (=*T. angulicosta* Gabb).

WHITE, CHARLES A.—*Correlation Papers. A Review of the Cretaceous Formations of North America.* U. S. Geol. Surv., Bull. No. 82, 1891, pp. 74-100.

The known facts regarding the character and distribution of the Cretaceous in North Carolina are briefly summarized. He expresses the opinion that both the marine and nonmarine divisions of the Cretaceous are, or originally were, continuous throughout the Atlantic border region.

1892.

DALL, WILLIAM HEALEY, and HARRIS, GILBERT DENNISON.—*Correlation Papers—Neocene.* U. S. Geol. Surv., Bull. No. 84, 349 pp., 3 maps, 3 pls., 43 figs.; Washington, 1892.

In this report a summary of all previously published literature describing the Miocene and Pliocene strata of the United States is given. The principal statements pertaining to North Carolina are largely taken from publications by Kerr.

GENTH, FREDERICK A.—*The Minerals of North Carolina.* U. S. Geol. Surv., Bull. No. 74, 119 pp.; Washington, 1891.

Calcite, limonite, siderite, pyrite, phosphate nodules, glauconite, and lignite are reported from numerous places in the Coastal Plain of the State, while vivianite is reported from Tertiary marl of Edgecombe County.

HOLMES, J. A.—*Character and Distribution of Road Materials.* Jour. Elisha Mitchell Sci. Soc., Pt. II, 1892, pp. 66-81.

The writer discusses briefly the value of the limestones contained in the Tertiary beds of the State for road-building purposes. Of these, the limestones exposed along the Northeast Cape Fear and Trent rivers are considered of greatest importance.

There is also a brief statement of the distribution of gravels, and their availability as road materials is discussed.

1893.

BOYLE, CORNELIUS.—*A Catalogue and Bibliography of North American Mesozoic Invertebrata.* U. S. Geol. Surv., Bull. No. 102, 1893.

COBB, COLLIER.—*Notes on the Deflective Effect of the Earth's Rotation as Shown in Streams.* Elisha Mitchell Sci. Soc. Jour., 1893, pp. 26-32.

Discusses the deflective effect of the earth's rotation on the courses

of streams. Cites examples of such deflection in various parts of the world, and notes particularly the apparent operation of this force on the streams of North Carolina.

HOLMES, J. A.—*Geology of the Sandhill Country of the Carolinas.* Geol. Soc. Amer. Bull., vol. 5, 1893, pp. 33-34.

Describes the character, stratigraphic relations, age, etc., of the deposits of the sandhill region of the Carolinas. Recognizes Cretaceous, Eocene, Lafayette, and Columbia deposits.

The Cretaceous deposits consist of several hundred feet of arkosic sands with subordinate clay beds. The upper surface is deeply eroded.

Eocene remnants are said to cap many hills at an elevation of 500 feet above tide-level. "The submergence during Eocene deposition could hardly have been less than 600 or 700 feet, and may have been several hundred feet more, and the Eocene waters for a short time may have covered a considerable part of the Piedmont Plateau and washed against the slopes of King's and Anderson's and the Sauratown Mountains" (p. 34).

The sands and loams of the Lafayette formation overlie unconformably both the Cretaceous and Eocene deposits. These, also, have been deeply eroded.

A mantle of sands and loams, classed as Columbia, overlies all older formations.

NITZE, H. B. C.—*Iron Ores of North Carolina. A Preliminary Report.* N. C. Geol. Surv., Bull. No. 1, pp. 21-239, pls. i-xx, figs. 1-58, maps. Raleigh, 1893.

Limonite is reported from Edgecombe, Pitt, Halifax, and Robeson counties, but the geological horizon is not stated. On the accompanying geological map the Tertiary is not separated into formations, as the author says that he does not have sufficient information to draw the formation lines.

1894.

HAYES, C. W., and CAMPBELL, M. R.—*Geomorphology of the Southern Appalachians.* Nat. Geog. Mag., vol. 6, 1894, pp. 63-126.

The probable connection of the Cape Hatteras axis and the Cincinnati uplift with a transverse fold in the Appalachian region, which is expressed in the deformed contour lines in the Cretaceous peneplain of the latter region, is discussed (p. 81).

1895.

ABBE, CLEVELAND (JR.).—*Remarks on the Cuspate Capes of the Carolina Coast.* Boston Soc. Nat. Hist., Proc., vol. 26, 1895, pp. 489-497.

Discusses the origin of the Cuspate Capes of the Carolina Coast.

1896.

DARTON, N. H.—*Artesian Well Prospects in the Atlantic Coastal Plain Region.* U. S. Geol. Surv., Bull. No. 138, 233 pp., 19 pls., Washington, 1896.

A brief résumé of the geology of the Coastal Plain is given in this report. A section across the State prepared by Prof. J. A. Holmes is included. Sections of wells in Wayne, Pender, and New Hanover counties, which penetrate Cretaceous beds, are also given.

DARTON, N. H.—*Notes on Relations of Lower Members of the Coastal Plain Series in South Carolina.* Geol. Soc. Amer., Bull., vol. 7, 1896, pp. 512-518.

The paper is of interest because the beds described constitute the South Carolina equivalents of formations recognized in North Carolina.

FONTAINE, WILLIAM M.—*The Potomac Formation in Virginia.* U. S. Geol. Surv., Bull. No. 145, 1896, 149 pp.

Again describing the supposed Potomac at Weldon, the author says: "In only one place, and in a very limited space, did I find the surface of the gneiss laid bare. This was in the channel of a small run that entered the river on the north side of and near the bridge head. Here a deposit, a few inches thick, of coarse, gray grit, with occasional large pebbles, is displayed. The material has all the lithological characters that distinguish the Potomac formation. It seems to owe its preservation to its firm union with the uneven surface of the gneiss" (p. 25).

HOLMES, J. A.—*Notes on the Kaolin and Clay Deposits of North Carolina.* Trans., Amer. Inst. Min. Engrs., vol. 25, pp. 929-936, 1896.

The author states that beds of laminated dark-colored Potomac clays containing in places lignite and pyrite, occur on the rivers crossing the Coastal Plain, notably along the Cape Fear River for 50 miles below Fayetteville. A vertical section of Prospect Hall Bluff, 93 miles above Wilmington, is given.

The following statements are made in regard to the Eocene: "Along the western border of the Coastal Plain region, especially in Moore and Harnett counties, there are limited exposures of siliceous Eocene deposits (overlying the Potomac series, and capping some of the sandhills), which have recently been tested for fire brick with very satisfactory results. These deposits are from 5 to 15 feet, or more, in thickness, and are overlain by but a few feet of loose sand" (p. 935). Analysis of Eocene fire clay two miles northeast of Spout Springs:

SiO_2	87.70
Al_2O_3	3.29
Fe_2O_3	2.81
CaO	.48
MgO	.40
Alkaline chlorides	1.48
Loss on ignition	3.15
	99.31

Mention is made of exposures of blue Miocene marl at various places in the Coastal Plain, especially on the Roanoke and Tar rivers, that may prove to be of some value for the manufacture of clay products.

He describes briefly the geography, distribution, and character of the Lafayette and Columbia formations (pp. 935-936).

1897.

RIES, HEINRICH.—*Clay Deposits and Clay Industry in North Carolina.* N. C. Geol. Surv., Bull. No. 13, 1897, 157 pp., 12 pls., 5 figs.

In this report the black clays occurring from 10 to 60 miles below

Fayetteville on Cape Fear River are regarded as Potomac. Special mention is made of the clays at Prospect Hall Bluff, an analysis of which is given. The clays occurring in the cuts at Spout Springs in Harnett County are erroneously referred to the Eocene, while those between Spout Springs and Fayetteville are regarded as of uncertain age, either Eocene or Cretaceous.

He describes the occurrence of clays in the Lafayette and Pleistocene formations and gives specific localities in various counties (pp. 102-138).

1898.

WOOLMAN, LEWIS.—*Fossil Mollusks and Diatoms from the Dismal Swamp, Virginia and North Carolina;* indication of the geological age of the deposits; with notes on the diatoms by Charles C. Boyer. Proc. Phila. Acad. Nat. Sci., 1898, pp. 414-424, 1898.

Fossils from the Dismal Swamp Canal, near Lilly, are described and the strata containing them referred to the late Pliocene or possibly the Pleistocene. They are correlated with the fossiliferous strata, near Croatan, N. C.

1899.

GLENN, L. C.—*The Hatteras Axis in Triassic and in Miocene Time.* Amer. Geol., vol. 23, pp. 375-379, 1899.

The writer believes that during both the Triassic and Miocene periods the central portion of the State of North Carolina was a region of much greater stability than the regions on either side, and that a line or belt extending from Cape Hatteras westward served as an axis, so that when the region to the north was depressed the region to the south was uplifted. and *vice versa.* The reason for this belief is the dissimilarity of the Triassic and Tertiary deposits of Virginia, Maryland, and New Jersey when compared with those of South Carolina and the Gulf States.

He asserts that the region of the so-called "Hatteras Axis" has been one of minimum movement since the beginning of Lafayette time.

1900.

HOLMES, J. A.—*The Cretaceous and Tertiary Section Between Cape Fear and Fayetteville, N. C.* Abstract, Science, new series, vol. 11, p. 143, 1900.

Brief mention is made of the great unconformity between the Cretaceous and the Tertiary, and the erosion intervals at the close of the Eocene and Lafayette.

HOLMES, J. A.—*The Deep Well at Wilmington, N. C.* Science, n. s., vol. 11, 1900, pp. 128-130.

Describes the character of the materials and the nature of the water encountered in this well. A thickness of 1,100 feet of Upper Cretaceous sediments was penetrated, at the base of which granite was encountered. On the basis of the contained fossils, Dr. Stanton, who identified them, classes the upper 720 feet of materials as Ripley and the remainder of the strata down to the granite as Eutaw. Potomac equivalents are absent.

1902.

DARTON, N. H.—*Norfolk Folio, Virginia-North Carolina.* U. S. Geol. Surv., Geol. Atlas of U. S., Folio No. 80, 4to, 4 pp., 2 maps, 6 figs., Washington, 1902.

The configuration of a portion of Camden and Currituck counties is described. The author states that the Pliocene probably underlies the entire Dismal Swamp region, though the paleontological evidence which he offers does not seem to be conclusive, and in the present report these strata are referred to the Pleistocene. The origin of the Dismal Swamp is also discussed.

1903.

COBB, COLLIER.—*Origin of the Sandhill Topography of the Carolinas.* Science, n. s., vol. 17, 1903, pp. 226-227.

Notes æolian cross-bedding in the sand accumulations. Comments on the similarity in composition of these sands to those of the present beaches, and states that this explains the origin of some of the topographic features.

1904.

COBB, COLLIER.—*The Forms of Sand-dunes as Influenced by Neighboring Forests.* Elisha Mitchell Sci. Soc. Jour., vol. 20, 1904, p. 14.

Discusses the factors which tend to prevent sand-dunes, which have been heaped up along the coast by east winds, from being blown back into the sea by west winds.

PRATT, JOSEPH HYDE.—*The Mining Industry in North Carolina During 1903.* N. C. Geol. Surv., Econ. Paper No. 8, 74 pp., map; Raleigh, 1904.

The shell limestones along the Northeast Cape Fear and Trent rivers are briefly described and statements are made concerning their use for structural purposes and as a source for lime (p. 56).

SLOAN, EARLE.—*A Preliminary Report on the Clays of South Carolina.* South Carolina Geological Survey, series 4, Bull. No. 1, 1904, 175 pp.

Describes and classifies the Coastal Plain deposits. He introduces the name "Hamburg clays" for the basal Cretaceous formation, and the name Middendorf beds for an immediately overlying Cretaceous formation. The "Hamburg clays" correspond to the Patuxent formation of the present report.

1905.

FULLER, M. L.—*Underground Waters of Eastern United States: North Carolina.* U. S. Geol. Survey Water Supply and Irrigation Paper No. 114, pp. 136-139, 1 fig.; Washington, 1905.

The article contains a very brief description of the Coastal Plain region of North Carolina.

WARD, LESTER F.—*Status of the Mesozoic Floras of the United States.* U. S. Geol. Survey, Mon. 48, 1905; Pt. I, text 616 pp.; Pt. II, 119 pls.

Describes briefly (pp. 385-392) the Cretaceous deposits exposed on Cape Fear River and some of its tributaries, and in the railroad cuts between Sanford and Fayetteville. Those appearing in the bluffs at Fayetteville are referred to the older Potomac of Virginia. Higher beds farther down

the river are referred to the newer Potomac. Of the river exposures taken collectively he states that "The section seems to be complete from the older Potomac through the marine Cretaceous, and the later Tertiary overlies the last." The beds exposed in the railroad cuts above mentioned are referred to the Tuscaloosa formation of Alabama.

1906.

CHAMBERLIN, T. C., and SALISBURY, R. D.—Geology, vol. 3, 1906. Lafayette, pp. 301-308. Columbia, pp. 447-454.

Describes the character, distribution, etc., of the Lafayette and Columbia formations and concludes that their origin is largely due to fluviatile and subaërial processes.

COBB, COLLIER.—*Notes on the Geology of Currituck Banks.* Elisha Mitchell Sci. Soc. Jour., vol. 22, No. 1, 1906, pp. 17-19.

Describes the physical character of these banks and discusses their origin. Expresses the view that the coast in the vicinity of Currituck Banks is now subsiding.

COBB, COLLIER.—*Where the Wind Does the Work.* Nat. Geog. Mag., vol. 17, No. 6, 1906, pp. 310-317, 10 figs. Elisha Mitchell Sci. Soc. Jour., vol. 22, No. 3, 1906, pp. 80-85.

Describes wind-blown sand-dunes and their migrations on the chain of low-lying sand reefs and islands along the Atlantic coast of North Carolina.

SALISBURY, ROLLIN D.—See CHAMBERLIN, T. C., and SALISBURY, R. D.

SANFORD, SAMUEL.—*Record of Deep Well Drilling for 1905.* U. S. Geol. Surv., Bull. No. 298, 1906, pp. 15-296.

Describes well sections at Kinston, Fort Caswell, and Pinehurst (pp. 245-246).

SHATTUCK, GEORGE B.—*Pliocene and Pleistocene Deposits of Maryland.* Maryland Geol. Survey, 1906, 237 pp., pls. 75.

A monographic study of the Pliocene and Pleistocene deposits of Maryland.

1907.

BERRY, EDWARD W.—*Coastal-Plain Amber.* Torreya, vol. 7, No. 1, 1907, pp. 4-6.

The presence of amber is noted in Cretaceous deposits near Blackmans Bluff on Neuse River, and near Parker Landing on Tar River, both in North Carolina.

BERRY, EDWARD W.—*Contributions to the Mesozoic Flora of the Atlantic Coastal Plain.* II. North Carolina. Torrey Botanical Club Bull., vol. 34, No. 4, 1907, pp. 185-206, pls. 11-16.

Notes the occurrence of 29 recognizable species of plant remains in the transitional Cretaceous beds of North Carolina, and of these 7 are described and figured as new. He correlates the beds provisionally with the Tuscaloosa formation of Alabama and the Raritan formation of New Jersey, but predicts that they will eventually prove to include representatives of both the upper Tuscaloosa and Eutaw formations and the Magothy and Raritan formations of New Jersey.

BERRY, EDWARD W.—*Cretaceous Floras in North and South Carolina.* Johns Hopkins University Circular, n. s., 1907, No. 7 (whole No. 199), pp. 79-91.

Notes the discovery in North and South Carolina of fossil plant localities which yield forms belonging to a remarkable Cretaceous flora of comparative modern aspect, originally described from Greenland by Oswald Heer, and now known to occur interruptedly at localities from New England to Alabama. A list of 15 species belonging to this flora, from a new locality at Court House Bluff, Cape Fear River, Bladen County, N. C., is given.

BERRY, EDWARD W.—*Contributions to Pleistocene Flora of North Carolina.* Jour. of Geol., vol. 15, 1907, pp. 338-349.

Announces the discovery of two Pleistocene plant localities in the Coastal Plain of North Carolina and gives a brief preliminary description of the fossil plants obtained. As regards their significance, he concludes that the temperatures were not lower than at the present time in the same latitude and may have been higher. The flora shows a very modern aspect and indicates a short lapse of time in a geological sense since the deposition of the beds.

COBB, COLLIER.—*Geology of Core Bank.* Science, n. s., vol. 25, 1907, p. 298. Elisha Mitchell Sci. Soc. Jour., vol. 23, No. 1, May, 1907, pp. 26-28.

Discusses the character and origin of Core Banks and states that the coast south of Hatteras is rising, and not subsiding.

JOHNSON, B. L.—*Pleistocene Terracing in the North Carolina Coastal Plain.* Science, n. s., vol. 26, 1907, pp. 640-642.

Describes a series of ocean-bordering terraces with estuarine reëntrants which together make up the principal surface features of the North Carolina Coastal Plain.

MCCARTHY, GERALD.—*Ground and Deep Waters of North Carolina.* Bull. of the North Carolina Board of Health, vol. 22, No. 1, 1907, pp. 1-14, 6 figs.

Discusses briefly and in a general way the geology of the Coastal Plain of the State.

SLOAN, EARLE.—*Geology and Mineral Resources (South Carolina).* Handbook of South Carolina, issued by the State Department of Agriculture, Commerce and Immigration, 1907. Chapter 5, pp. 77-145, map, pp. 138-139.

Classifies the Coastal Plain formations of the State. Introduces the names Black Creek shales and "Burches Ferry marls" for Upper Cretaceous formations corresponding respectively to the Black Creek and Peedee formations of North Carolina, as defined in the present report.

STEPHENSON, L. W.—*Some Facts Relating to the Mesozoic Deposits of the Coastal Plain of North Carolina.* Johns Hopkins University Circular, n. s., 1907, No. 7 (whole No. 199), pp. 93-99.

The author recognizes three divisions in the Coastal Plain Mesozoic deposits of the State. The lithologic and paleontologic characters, the stratigraphic relations and areal extent of these divisions are briefly summarized. For the oldest, which is correlated approximately with the Patuxent formation of Virginia and Maryland, the name Cape Fear

formation is proposed. For the next younger division, which is correlated provisionally with the Tuscaloosa formation of Alabama with the suggestion that they may prove to include equivalents of the Eutaw formation, the name "Bladen" formation is proposed. The youngest division is correlated with the Ripley of Alabama and Mississippi, and the latter designation is applied to it.

In the present report the names Patuxent, Black Creek, and Peedee replace the names "Cape Fear," "Bladen," and "Ripley," respectively.

In connection with the discussion of the Mesozoic strata some brief statements are made in regard to the distribution of the Eocene and Miocene of the State.

1908.

BERRY, EDWARD W.—*Some Araucarian Remains from the Atlantic Coastal Plain.* Torrey Bot. Club Bull., vol. 35, No. 5, 1908, pp. 249-260, pls. 11-16.

Describes two new species from the "Bladen" (Black Creek) formation of North Carolina, namely, *Araucaria bladenensis* and *A. jeffreyi.* States that the former "is preëminently the type fossil of the Bladen formation of North Carolina." States that the beds in which these forms are found should probably be correlated with the Magothy formation of New Jersey.

BERRY, EDWARD W.—*A Mid-Cretaceous Species of Torreya.* Amer. Jour. Sci., 4th ser., vol. 25, 1908, pp. 382-386.

A new species of Torreya, *Tumion carolinianum,* from Cretaceous beds of Rockfish Creek near Hope Mills, Cumberland County, is described.

SLOAN, EARLE.—*A Catalogue of the Mineral Localities of South Carolina.* South Carolina Geological Survey, series 4, Bull. No. 2, 1908, 505 pp. and map under back cover.

The geology of the Coastal Plain region of the State is summarized, the extent and character of the various Cretaceous, Tertiary, and Quaternary formations being indicated (pp. 434-485).

1909.

BERRY, EDWARD W.—*Additions to the Pleistocene Flora of North Carolina.* Torreya, vol. 9, No. 4, April, 1909, pp. 71-73, 2 figs.

Enumerates 5 species from near Weldon, N. C., not previously listed from the Pleistocene of the State, and figures two of them.

STEPHENSON, L. W.—*Cretaceous Geology of the Carolinas and Georgia.* Science, new series, vol. 30, 1909, pp. 124-125.

Summarizes briefly the stratigraphy of the Cretaceous deposits of North Carolina, indicating their approximate correlations with other Cretaceous deposits in the Coastal Plain to the north and to the south, and discussing briefly their possible correlations with Cretaceous deposits in the Western Interior.

1910.

BERRY, EDWARD W.—*Contributions to the Mesozoic Flora of the Atlantic Coastal Plain.* V. North Carolina. Torrey Botan. Club, Bull., vol. 37, 1910, pp. 181-200, pls. 19-24.

Describes 29 new species of fossil plants from the Black Creek formation of North Carolina.

CLARK, WM. B.—*Results of a Recent Investigation of the Coastal Plain Formations in the Area between Massachusetts and North Carolina.* Bull. Geol. Soc. Amer., vol. 20, pp. 646-654, pl. 111. (Read December, 1909.)

Describes the Cretaceous formations of North Carolina and points out their relations to the Cretaceous deposits of the Northern Coastal Plain and of the Gulf. The question of their correlation is considered in much detail.

THE CRETACEOUS FORMATIONS.

BY L. W. STEPHENSON.

HISTORICAL REVIEW.

The earliest account of strata now classed as Cretaceous, in the State of North Carolina, was furnished by William Bartram[1] in 1791. In the course of his travels through the Southern States he came to Ashwood on Cape Fear River, situated 3 or 4 miles below Whitehall in Bladen County, the exact site of which is not at present known. A river bluff at this point attracted his attention, and in the published account of his travels he describes in considerable detail the materials therein exposed. On account of its historic interest the description is quoted (pp. 472-479), as follows:

> This perpendicular bank of the river, by which the waters swiftly glide along, discovers at once the various strata of the earth of this low maritime country. For the most part, the upper stratum consists of a light, sandy, pale yellowish mould or loam, for 10 or 12 feet in depth * * *; this sandy mould or loam lays upon a deep bed of black or dark slate-colored saline and sulphureous earth, which is composed of horizontal thin flakes or laminæ, separable by means of very thin, almost imperceptible veins or strata of fine micaceous particles * * *; other places present to view strata of heterogeneous matter, lying between the upper loamy stratum and the bed of black saline earth, consisting of various kinds of seashells, some whole, others broken to pieces, and even pulverized, which fill up the cavities of the entire shells, and the interstices betwixt them; at other places we observe, two or three feet below the surface or virgin mould, a stratum of four, five, or six feet in depth, of brownish marl, on a bed of testaceous rocks; a petrification composed, apparently, of various kinds of seashells, belemnites, sand, etc., combined or united with a calcareous cement; * * *. And again we observe shells, marcacites, belemnites, dentes carchariæ, with pieces of wood transmuted, black and hard as sea coal, singly interspersed in the black vitriolic strata of earth; * * *.

The next account of materials falling under this class was given by Denison Olmsted[2] in 1827. He describes a deposit of so-called copperas at Spring Bank, 7 miles below Waynesborough (Goldsboro of to-day) in Wayne County, as follows:

[1]Travels through North and South Carolina, etc. Philadelphia, 1791; London, 1794.
[2]Geology of North Carolina, Pt. II, 1827, pp. 87–141 (especially pp. 98–99).

About 12 feet above the bed of the river the eye meets with a layer of greensand, embracing a black, charry substance, which, on examination, is found to be fossil wood, in the state of coarse coal. Here may be found by digging, the trunks, branches, and bark of trees, forming a kind of subterranean forest. In company with this stratum is found the copperas, more or less mixed with sand, from which it is easily separated by lixiviation, as ashes are lixiviated in making soap.

He states that these copperas deposits extend for more than 100 miles along the banks of the river.

In the same year Elisha Mitchell[3] described briefly an occurrence of blue marl on Northeast Cape Fear River at South Washington. This was later referred by Hodge to the "Secondary formation," and by Lyell to the Cretaceous of New Jersey.

In this same year also Lardner Vanuxem,[4] through Prof. S. G. Morton, proposed a classification of the Atlantic Coastal Plain deposits, dividing them into three major divisions, namely, in ascending order, the Secondary, Tertiary, and Alluvial formations. The only locality in North Carolina mentioned as belonging to the "Secondary formation" was near Ashwood on Cape Fear River. Doubtless this is the exposure described by Bartram in 1791.

No further contributions were made to the knowledge of the Cretaceous in this State until 1841, when James T. Hodge,[5] in the account of his travels in the Southern States, described briefly the marl locality at South Washington. He mentions the occurrence of *Exogyra costata, Belemnitella, Plagiostoma palagicum,* and *Anomia ephippium,* and on the evidence of these fossils correlates the rock with the "Secondary formation."

The following year the same locality was visited by Charles Lyell. In several publications appearing between the years 1842 and 1845[6] he correlated the marl definitely with the New Jersey Cretaceous marl and with the Cretaceous of Europe. A new species of oyster, *Ostrea subspatulata,* obtained by Lyell at this locality, was described and figured by Edward Forbes[7] in 1845.

The limestone and phosphate conglomerate in the vicinity of Wilmington, previously regarded by Hodge and others as an upper "Secondary" deposit or a deposit interposed between the Cretaceous and the Eocene, was referred by Lyell to the Eocene.

[3]Geology of North Carolina, Pt. III, Raleigh, 1827, 27 pp. (especially p. 14).
[4]Acad. Nat. Sci., Philadelphia, Jour., vol. 6, 1827, pp. 59–71.
[5]Am. Jour. Sci., vol. 41, pp. 332–344, 1841.
[6]Geol. Soc., London, Proc., vol. 3, 1842, p. 736. Am. Jour. Sci., vol. 47, 1844, pp. 213-214. Travels in North America, etc., 2 vols., New York, 1845 (especially vol. 1, p. 156). Geol. Soc., London, Quart. Jour., vol. 1, 1845, pp. 55–60.
[7]Geol. Soc., London, Quart. Jour., vol. 1, 1845, pp. 61–62.

The deposits in South Carolina referable to the "Secondary formation" were described by Edmund Ruffin[8] in 1843. The name *Peedee* is applied to a so-called marl bed outcropping on lower Great Peedee River from Jeffreys Creek southward. He describes, but does not name, a dark shale or clay which immediately underlies the Peedee bed. The Peedee is essentially the same terrane as that designated by Sloan, in 1907, the "Burches Ferry marl," while the dark clay forms a part of the Black Creek shale of the same author.

In 1848, Prof. Michael Tuomey[9] correlated the Cretaceous strata recognized in South Carolina, principally on lower Great Peedee River and its tributaries, with the Cretaceous beds outcropping on Cape Fear River in North Carolina.

The greensands exposed in the bluffs of Cape Fear River below Elizabethtown and at Wilmington were definitely correlated with the Cretaceous by Prof. Ebenezer Emmons[10] in 1852. He mentions the occurrence of the characteristic Cretaceous fossils *Exogyra costata* and *Belemnitella* in the greensands. He treats at considerable length the subject of the value of the Cretaceous greensand marls as fertilizers.

The report of Professor Emmons[11] on the "Agriculture of the Eastern Counties," published in 1858, adds a few additional facts to those already known concerning the Cretaceous strata. Detailed descriptions are given of several of the bluffs on Cape Fear River below Elizabethtown. Sandbeds beneath Miocene shell marl, regarded as probably of Eocene age, are said to extend from Browns Landing, 24 miles below Elizabethtown, upstream nearly to Fayetteville. These beds are now referred to the Cretaceous. Cretaceous greensands are mentioned as present on Neuse River at Kinston. Light-gray sands occurring beneath shell marls [Miocene] at Tarboro on Tar River are correctly referred by him to the Cretaceous, but he regards them as interbedded in the greensand, and not belonging to a lower division of the Cretaceous, as is now known to be the case. The report contains descriptions and figures of a number of Cretaceous vertebrate and invertebrate fossils.

The first attempt to correlate the North Carolina Cretaceous with deposits in the Gulf region was made by T. A. Conrad in 1871. The following is quoted from a letter written by him from Greenville, N. C., to J. D. Dana, and published in the American Journal of Science:[12]

[8]Report of the Commencement and Progress of the Agricultural Survey of South Carolina, Columbia, S. C., 1843 (especially pp. 7, 24–27).

[9]Geol. of South Carolina, Columbia, S. C., 1848 (especially pp. 133–139).

[10]Geol. of North Carolina, Raleigh, 1852 (especially pp. 47, 72, 74, 107–109).

[11]Raleigh, 1858 (especially pp. 78–100, 193–314).

[12]3d ser., vol. 1, 1871, pp. 468–469.

At Colonel Yellowby's marl pit, where digging is now in progress, I found the Miocene about 3 or 4 feet in thickness, resting on black Cretaceous sand with black gravel, and containing characteristic Ripley group fossils. It is here that a profusion of Belemnites is thrown up by the laborers, over the Miocene marl heap, and give rise to the opinion that they occur in the Miocene marl.

At Snow Hill, 22 miles from here in Greene County, the Ripley group is finely developed, containing closely packed specimens of the Ripley species in perfect preservation.

The most complete and comprehensive report on the geology of the State afforded by the literature even to the present time is that of Prof. W. C. Kerr,[13] which appeared in 1875. The Cretaceous is described (pp. 147-149) as being visible only on the river bluffs of the southeastern portion of the State from the Neuse and its tributary, Contentnea Creek, southward. He elsewhere refers, however, to outcrops on Tar River (see p. 191) still farther to the northward. His description of the Cretaceous is quoted:

It is best exposed in the bluffs along the Cape Fear between Fayetteville and Wilmington. The rocks of this system (everywhere very slightly compacted) are, for 50 to 60 miles below Fayetteville, sandstones, clay slates and shales, 30 to 40 feet thick, in many places dark to black and very lignitic, with projecting trunks and limbs of trees, and at a few points full of marine shells. These beds Dr. Emmons regards as probably eocene. For 40 to 50 miles above Wilmington, and in all the other river sections, the rock is a uniform dark, greenish-gray, slightly argillaceous sandstone, massive, and showing scarcely any marks of bedding. This sandstone everywhere contains a small percentage of glauconite, and is in fact the representative of the true greensand * * *; but westward, higher up the Cape Fear, the beds lose entirely their glauconitic and calcareous character, and become more clayey and frequently black-lignitic with embedded trunks, limbs, and leaves of trees; and not unfrequently it is composed of sandy accumulations exhibiting much false bedding. These beds extend a hundred miles up the Cape Fear from Wilmington. It is probably the same lignitic member of this series which appears at low-water in the Neuse, at the railroad bridge near Goldsboro. The Cretaceous beds of North Carolina are not usually very rich in fossils, the greensand containing generally scattered specimens of belemnites, ostrea larva, exogyra costata, and an occasional anomia.

The following fossil localities are named: Kelleys Cove, Cape Fear River, 40 miles [46 miles] above Wilmington, in a stratum 2 to 4 feet thick; and Snow Hill, on Contentnea Creek, Lenoir County, where in a line of bluffs several hundred yards long and 20 to 40 feet high Cretaceous shells occur in a sandy marlite 10 to 12 feet thick at base, which he regards as representing a Ripley horizon.

[13]Geol. of North Carolina, 1875 (especially pp. 147–149).

In an appendix accompanying Professor Kerr's report T. A. Conrad describes 46 new species of Cretaceous mollusks, and states that they represent the Ripley of Mississippi. He includes a synopsis of the Cretaceous mollusca of North Carolina.

Six new species of mollusks from the Cretaceous of North Carolina were described by Gabb[14] in 1876. Two of these were from Snow Hill, but the exact localities from which the remaining were obtained is not indicated.

In 1888, W J McGee[15] described materials at Weldon, N. C., supposed by him to be a southward continuation of the Potomac group of Virginia, as follows:

> The southernmost observed occurrence of the formation is at Weldon, N. C., where a bed of obscurely stratified arkose, interspersed with well-rounded quartzite pebbles, appears in the north bank of the Roanoke beneath the railway bridge. The deposit rests on an unequally eroded surface of gneiss, is not over a foot thick, and is unfossiliferous; but its composition and structure are characteristic, and there is little doubt as to its identity.

In Federal Survey reports appearing in 1889[16] and 1896[17] William H. Fontaine, who was engaged in a study of the plant remains in the Potomac group, accepted McGee's interpretation regarding the age of the materials at Weldon. Recent investigations have shown the probable absence of Potomac equivalents in this immediate vicinity.

The general stratigraphic conditions in the lower Cape Fear River region were described by Prof. W. B. Clark[18] in 1890. He shows that the Cretaceous greensand marl occupies the base of the series of formations exposed.

The same year Fontaine[19] announced the discovery of Potomac strata at Haywood, Chatham County, N. C., but later work has thrown doubt upon the correctness of this interpretation.

Dr. C. A. White's correlation paper on the Cretaceous formations of North America,[20] which appeared in 1891, contains a brief review of the Cretaceous of North Carolina. He quotes Kerr's discussion regarding the marine division. Concerning the nonmarine division [Potomac], he says:

> It is not probable that any extensive exposures of the nonmarine division of the Cretaceous exist in North Carolina, and those now known are few and

[14]Acad. Nat. Sci., Proc., Phila., 1876, pp. 276-324.
[15]Am. Jour. Sci., 3d ser., vol. 35, 1888, pp. 120-143 (especially p. 126).
[16]U. S. G. S. Monog. 15, Text, 1889 (especially pp. 45-46).
[17]U. S. G. S. Bull. 145, 1896 (especially pp. 24-25).
[18]Bull. Geol. Soc. Amer., vol. 1, 1890, pp. 537-540.
[19]Tenth Ann. Rept. U. S. Geol. Survey (1888-1889), 1890, p. 174.
[20]Correlation Papers—Cretaceous. U. S. Geol. Survey Bull. No. 82, 1891; North Carolina, pp. 91-92.

unimportant, except that they demonstrate its existence there and afford presumptive evidence that the formation is, or originally was, continuous throughout the whole length of the Atlantic border region.

A vertical section from Haywood to New Bern, constructed from data derived from Kerr's report of 1875, is given.

An important contribution to the literature of the Carolina Cretaceous was made by J. A. Holmes[21] in 1893. The following general statements are made concerning the Cretaceous deposits along a portion of the inland margin of the Coastal Plain region:

That part of this region which lies between the Neuse and Savannah rivers has been examined more particularly, and in this region the following sections will indicate fairly well the geologic structure:

(*a*) A series of cross-bedded, medium to coarse arkose sands lying on the irregularly eroded surface of the crystalline rocks. These beds, which are classed provisionally as Cretaceous, contain in the upper layers in places lenses of clay and occasional thin beds and seams of lignitic material. They have been deeply eroded, their present surface rising nearly to the tops of the highest hills and sinking to the level of the deeper valleys.

The thickness of these sands is said to be several hundred feet. They are overlain by remnants of Eocene deposits, by loams and ferruginous sands of the Lafayette formation, also partly eroded away, and a surface mantle of sands and loams classed as Columbia. In this paper the author does not attempt to differentiate these sands as between Lower and Upper Cretaceous, but in a later publication (1896)[22] he correlates them, as well as other Cretaceous deposits in the State, with the Potomac (Lower Cretaceous) of Virginia, as indicated in the following quotation:

In the Potomac (Lower Cretaceous) formation there are extensive beds of laminated, dark-colored clays, exposed along the banks of rivers crossing the Coastal Plain region, notably on the Cape Fear River, for 50 miles below Fayetteville. These clays are usually dark in color, owing to the vegetable matters which they contain; and, in some cases, they are highly lignitic. The thin laminæ of clay are frequently separated by still thinner partings of sand; and frequently within a short distance (from a few feet to a few hundred feet) the clay laminæ become thin and disappear, while the sand partings gradually thicken, so that the whole assumes the character of a sand-bed instead of a clay-bed. * * *

Along the western border of the Coastal Plain region, especially in Moore and Harnett counties, there are limited exposures of siliceous Eocene deposits (overlying the Potomac series, and capping some of the sandhills). * * *

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[21]Abstract, Geol. Soc. Amer., Bull., vol. 5, 1893, pp. 33–35.
[22]Trans., Am. Inst. Min. Engrs., vol. 25, 1896, pp. 929–936.

Heinrich Ries[23] in 1897 followed Holmes in referring the deposits along Cape Fear River 10 to 60 miles below Fayetteville to the Potomac group. Clays in the railroad cuts at Spout Springs, which should have been referred to the Potomac, were regarded by him as Eocene.

The first data throwing light on the character of the deeper Coastal Plain deposits near the coast was furnished by Holmes[24] in 1900. He describes the section of a deep well drilled at Wilmington, N. C., in which were penetrated 1,109 feet of Upper Cretaceous strata, at the base of which granite was encountered. Dr. T. W. Stanton, to whom the fossils obtained were submitted, referred the upper 720 feet of strata to the Ripley and the remainder down to the granite to the Eutaw. The section is especially interesting as showing the absence of beds representing the Lower Cretaceous, between the Upper Cretaceous and the basal granite.

The Cape Fear River section was discussed by Lester F. Ward[25] in 1905. He describes the river bluffs at Fayetteville and refers them to the older Potomac of Virginia, stating that the beds of arkose probably represent the "Rappahannock freestone," and the interstratified clays probably correspond to the clay lenses in the "James River deposits." The older Potomac beds are said to be transgressed by marine deposits which occupy the top of the bluffs nearly the whole distance. The latter statement is not upheld by the facts as shown by the recent studies of the region. Higher beds farther down the river, on the evidence of imperfect dicotyledonous leaves, are referred to the newer Potomac. Of the Cape Fear section as a whole he says: "The section seems to be complete from the older Potomac through the Marine Cretaceous, and the later Tertiary overlies this last." He regards the arkosic deposit at Haywood as Potomac. The upper beds along the railroad between Sanford and Fayetteville are referred to the Tuscaloosa, apparently upon lithologic grounds. The exposures in the bed of Little River where the railroad crosses that stream are correctly regarded as older Potomac. The supposed Potomac at Weldon is regarded as still problematical.

A résumé of the results of field studies carried on in North Carolina by L. W. Stephenson during the years 1905 and 1906 appeared in 1907.[26]

Three divisions are recognized in the Mesozoic deposits of the Coastal Plain, and their character, geographic distribution, etc., are described.

[23]North Carolina Geological Survey, Bull. No. 13, 1897, p. 46.
[24]Science, n. s., vol. 11, 1900, pp. 128–130.
[25]U. S. Geol. Survey, Mon. 48, 1905 (especially pp. 390–392).
[26]Johns Hopkins University Circular, n. s., 1907, No. 7 (whole number 199), pp. 93–99.

The oldest, for which he proposes the name "Cape Fear" formation, is correlated approximately with the Patuxent formation of Virginia. For the next younger division, which is correlated provisionally with the Tuscaloosa formation of Alabama, the name "Bladen" formation is proposed. The youngest division is correlated with the Ripley of the Gulf region, and the name "Ripley" formation is employed to designate it. The names "Cape Fear," "Bladen," and "Ripley" correspond respectively to the names Patuxent, Black Creek, and Peedee as used in the present report.

During the same year two important contributions were made by E. W. Berry, relating to collections of fossil plants made by himself and Stephenson from the "Bladen" formation during the two preceding years. Lists are given, a number of new species are described and figured, and the significance of the flora is discussed. In the first of these papers[27] he discusses the age of the plant-bearing beds as follows:

> Because of their geographical position these beds should be provisionally correlated with the Tuscaloosa formation of Alabama; with this reservation, however, that the Tuscaloosa flora, as far as it is known, coincides with that of the Raritan. Lithologically these North Carolina beds are much more like the Magothy of New Jersey, Delaware, and Maryland than they are like the Raritan, and it seems probable that when the problem has been worked out for the whole Coastal Plain it will be found that the Tuscaloosa formation of Alabama as a whole includes sediments of older Potomac, Raritan, and Magothy age, while what is here called the Tuscaloosa formation in North Carolina, already differentiated from the older Potomac, includes phases corresponding to both the Raritan and Magothy formations of the more northern portions of the Coastal Plain and to the upper Tuscaloosa and Eutaw formations of the Gulf region.

In the second,[28] discussing the broader significance of the "Bladen" flora, he says:

> The remarkable flora, of a comparative modern aspect which seems to have evolved in the Arctic region, and which migrated southward over eastern North America during the Mid-Cretaceous, has been discovered at a large number of localities during the last decade. Originally described by Oswald Heer from the west coast of Greenland, it is now known from Massachusetts, the southern New England islands from Martha's Vineyard to Brooklyn, from Staten Island, and from the Raritan and Magothy formations of New Jersey, Delaware, and Maryland. From Maryland southward there has been a long break in the record, no plants having been known from the Potomac to the Chattahoochee, or a distance of about 800 miles. It is the purpose of the following brief note to partially bridge over this intervening area and record this Mid-Cretaceous flora from both North and South Carolina.

[27]Bull. of the Torrey Botanical Club, vol. 34, No. 4, 1907, pp. 185–206, pls. 11–16.
[28]Johns Hopkins University Circular, n. s., 1907, No. 7 (whole number 199), pp. 79–91.

In the same paper, discussing the distribution of fifteen well-known forms, most of which come from Court House Landing, Cape Fear River, he says: "Of these, seven were originally described from Greenland, seven from the Dakota group of the West, and seven from the Raritan formation of New Jersey. Four species have a European distribution, * * *." The European species all occur in the Cenomanian, and one of these also ranges up into the Senonian.

In 1907, Earle Sloan[29] introduced the name "Burches Ferry marls," using it for essentially the same terrane as that to which Ruffin had in 1843 applied the name Peedee.

Three new "Bladen" forms were described by Berry in 1908. Two of these belong to the genus *Araucaria*,[30] namely, *Araucaria bladenensis* and *Araucaria jeffreyi*. Of the former he says:

> It is preëminently the type fossil of the Bladen formation of North Carolina, single leaves or even fragments being quite characteristic and easy of recognition.

Concerning the correlation of the beds in which these remains were collected, he says:

> The New Jersey material comes from beds of the Magothy formation, very probably of Cenomanian age. The Carolina forms are from beds which differ in age but slightly, if at all, from those of New Jersey, although they may be somewhat older, possibly synchronous with the Raritan formation of New Jersey and the Tuscaloosa formation of Alabama, the question of exact correlation being under active investigation at the present time.

The third[31] is a species of Torreya, namely, *Tumion carolinianum*.

An abstract of a paper read before the Geological Society of Washington by L. W. Stephenson appeared in 1909.[32] The Cretaceous is divided into three formations; the oldest, the "Cape Fear" formation, is referred to the Lower Cretaceous; the "Bladen" formation which overlies the "Cape Fear" formation unconformably, and the third or upper division formerly designated the "Ripley" formation by the same author, which overlies the "Bladen" formation conformably, are referred to the Upper Cretaceous. On account of uncertainty which has arisen regarding the exact meaning of the term Ripley as employed in the Gulf region, the author suggests that the name "Burches Ferry"

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[29]Handbook of South Carolina, issued by the State Department of Agriculture, Commerce and Immigration. Columbia, S. C., 1907. Chapter 5, Geology and Mineral Resources, pp. 77–145 (especially pp. 85–88).

[30]Torrey Bot. Club, Bull., vol. 35, No. 5, 1908, pp. 249–260, pls. 11–16.

[31]Am. Jour. Sci., vol. 25, 1908, pp. 382–386.

[32]Science, n. s., vol. 30, 1909, pp. 124–125.

formation, applied by Sloan to the southward continuation of the same terrane, might appropriately be substituted for that of Ripley. Brief statements are made regarding the probable correlations of these divisions with Cretaceous deposits in other regions. The names "Cape Fear," "Bladen," and "Ripley" correspond respectively to the names Patuxent, Black Creek, and Peedee, of the present report.

In 1910, E. W. Berry[33] described 29 new species of fossil plants from the Black Creek formation of North Carolina.

Prof. W. B. Clark presented a paper[34] in 1909 before the Geological Society of America on the results of the work by himself and associates in the Coastal Plain region between Massachusetts and South Carolina, in which he discusses the Cretaceous formations of North Carolina and points out their relations to the Cretaceous deposits of the Northern Coastal Plain and of the Gulf. The question of their correlation is considered in much detail.

DIVISIONS OF THE CRETACEOUS.

Previous to the investigations furnishing the data for the present report, there had been little attempt on the part of geologists working in the region to differentiate the Cretaceous deposits of North Carolina into formations. It was recognized by Professors Holmes and Ward that the basal Cretaceous beds were the probable equivalent of the Potomac, but neither were clear in their definition of the upper stratigraphic limits of these Lower Cretaceous representatives; and, in fact, Holmes included in this division certain of the beds on Cape Fear River now known to belong unquestionably to the Upper Cretaceous.

The recent investigations in the North Carolina Coastal Plain have led to the recognition of three Cretaceous divisions designated in the ascending order: the Patuxent ("Cape Fear") formation of Lower Cretaceous age, and the Black Creek ("Bladen") and Peedee ("Burches Ferry") formations of Upper Cretaceous age.

As will be seen by referring to the geologic map (Plate XVII, in pocket), these three formations have their widest areal development in the southern part of the Coastal Plain portion of the State. To the northward the area of outcrop narrows, being transgressed more and more by younger, Tertiary strata until at the Virginia line the Cretaceous strata are entirely overlapped and concealed. The best continuous series of Cretaceous exposures is furnished by the bluffs of Cape Fear River and its tributaries, the strata appearing at intervals all the way

[33]Torrey Botan. Club, Bull., vol. 37, 1910, pp. 181–200, pls. 19–24.
[34]Bull. Geol. Soc. America, vol. 20, pp. 646-654, pl. 111, 1910.

from the fall line to Wilmington, a distance of over 100 miles. The Cape Fear region furnishes not only the widest area of Cretaceous strata in this State, but also the widest area at right angles to the fall line in the Coastal Plain region east of the Mississippi River.

Plate XXX, p. 342, is a section constructed across the Coastal Plain, at right angles to the general strike of the strata from Cameron to Wrightsville, which shows the stratigraphic relations of the three recognized Cretaceous formations.

LOWER CRETACEOUS.

PATUXENT FORMATION.

Name.—The name, Patuxent formation, was proposed by Prof. Wm. Bullock Clark in 1897[35] to designate the basal formation of the Potomac group in Maryland. The name is derived from Patuxent River, Maryland. The formation as defined consists of arkosic sands with subordinate amounts of sandy clay, having an estimated thickness of 150 feet. The division was described in detail in later publications by Clark and Bibbins.[36]

The terrane in North Carolina, under consideration, was first differentiated by the writer[37] in 1907, and the name "Cape Fear" formation was used to designate it. The division was then regarded as the probable equivalent of the Patuxent formation of Maryland. Although there is no paleontologic evidence to support the correlation, the investigations carried on in the region since the publication of the above paper have led to the conviction, based upon physical criteria, that the "Cape Fear" formation is in fact the southward extension of the Patuxent formation, but with its surface connection with that formation interrupted in the region of southern Virginia and northern North Carolina by overlapping Tertiary strata, as is the case at various points farther north in Virginia and Maryland.

Definition.—The Patuxent formation outcrops in a belt beginning at Roanoke River, where the river forms the boundary between the eastern halves of Northampton and Halifax counties, and passing thence to the southwest through the following counties: Edgecombe, northern Pitt, Wilson south of the town of Wilson, northern Greene, the northern half of Wayne, Johnston south of Smithfield, northern Sampson, southern Harnett, almost all of Cumberland, southern Moore, northern Robeson, probably all of Scotland, and southern Richmond to the South Carolina line. Beyond this line it passes into South Carolina through

[35] Maryland Geol. Surv., vol. 1, 1897, p. 190.

[36] Jour. of Geol., vol. 5, 1897, pp. 481-485. Geol. Soc. Amer., Bull., vol. 13, 1902, pp. 187-214.

[37] Johns Hopkins University Circular, n. s., 1907, No. 7 (whole No. 199), pp. 93-99.

Marlboro County and from thence, by way of Camden, Columbia, and Hamburg, into Georgia in the vicinity of Augusta. (See geologic map, Plate XVII, in pocket.)

The formation where present forms the basal division of the deposits of the Coastal Plain and rests directly upon the eroded surface of the basement rocks. The latter consist for the most part of early Paleozoic or Proterozoic igneous and metamorphic rocks, but also to a limited extent of sedimentary deposits of Triassic age (Newark). The upper surface of the basement rocks where they are overlain by the deposits of the Coastal Plain is very uneven. This is true not only with respect to minor details, but likewise as regards certain larger features. This unevenness is indicated, first, by the eastward extension at the surface of long tongues of the older rocks; second, by the outcrop of isolated patches of these rocks at considerable distances to the east of the Piedmont border; and, finally, by the depths at which they have been encountered in wells at various places.

The formation is overlain unconformably by the Black Creek ("Bladen") formation, or, where that is absent, by overlapping strata of the Eocene, Miocene, Pliocene, or Pleistocene periods. The beds of the Black Creek formation form the immediate superjacent covering along the southeastern edge of the belt of Patuxent occurrences. The observed width of overlaps of these beds above water level varies from a few miles to a maximum of at least 12 miles, the greatest width being in the valley of Cape Fear River in southeastern Cumberland County. The undulating Patuxent-Black Creek contact has been observed at various places on Cape Fear, Neuse, Contentnea, and Tar rivers.

The relations of the Patuxent formation to Tertiary and younger beds will be discussed in the order of age, beginning with the oldest. But one area of Eocene is known within the belt. This is in Harnett County, about 3 miles northeast of Spout Springs, where a bed of siliceous limestone, probably of very limited extent, is poorly exposed near the top of a hill. Its vertical position is perhaps about 300 feet above sea-level. It is believed to rest upon the Patuxent formation and is probably overlain by a surface covering of the Lafayette formation. From the southwestern edge of Wilson County northeastward to Roanoke River the Patuxent formation is perhaps continuously overlain by overlapping beds of Miocene age, except where the latter have been removed by stream erosion and by Pleistocene terracing processes along the valleys. From Neuse River to Roanoke River the observed Patuxent exposures are all low, nowhere exceeding 15 feet above water level of the streams. It is probable that from Wilson County north-

eastward the thickness of the overlapping Miocene everywhere exceeds the thickness of that portion of the Patuxent beds appearing above water level. In this region the Miocene beds transgress westward entirely across and several miles beyond the Patuxent belt, resting directly upon the surface of the basement rocks.

The next younger division having a contact relationship with the Patuxent formation is the Lafayette formation. This relationship exists, so far as known, only in the sandhill country of the southwestern portion of the Coastal Plain province. The term sandhills has been applied to a series of rolling hills covering portions of Richmond, Scotland, Moore, Cumberland, and Harnett counties, whose elevations vary from a little over 200 feet to perhaps 500 feet. In this region the comparatively thin and more or less discontinuous Lafayette covering rests unconformably upon an eroded Patuxent surface whose broader topographic features seem to correspond closely to the present surface topography.

To the east of the sandhills and throughout the entire remaining extent of the belt of Patuxent outcrop not covered by Miocene or Lafayette strata, the Patuxent beds are concealed by surficial Pleistocene terrace coverings. Indeed, were it not for occasional stream cuttings, gullies, or artificial excavations, the older beds would be everywhere effectually concealed.

The strata of the Patuxent formation consist of sands and clays and various intergradations of arenaceous clays and argillaceous sands. The sands are fine to very coarse in texture, the individual grains being, as a rule, angular. They are in most places arkosic, and locally contain a large percentage of pure white kaolin grains. Muscovite mica is a common constituent and in places is present in large amounts. One specimen from near the base of the section at Fayetteville resembles a decomposed mica schist, the mica flakes being arranged in a general way parallel with the bedding planes and having diameters ranging up to 1/8 inch. In this same specimen biotite mica is present in considerable amount, the individual flakes being smaller than those of muscovite. The sands are light gray to gray and greenish-gray in color, but locally are stained various shades of red, yellow, and brown by the hydrous oxides of iron.

The clays are everywhere more or less arenaceous, and fine mica flakes are generally present in greater or lesser amount. The colors range through dark drab, drab, greenish-drab, gray, and greenish-gray, or the materials may be mottled or more or less uniformly colored with purplish and reddish tints.

In most of the river exposures in North Carolina both the sands and

clays are, as a rule, very compact, but nearer the Piedmont border the sands are more commonly of a loose texture. In some instances the arkosic sands are slightly indurated, forming a soft friable sandstone rock.

Iron sulphide, probably in the form of marcasite, was observed in a clay bed in the section at milepost 105 on the Neuse River and also in clay beds at some of the exposures on Roanoke River.

A small amount of lignite was observed at one or two places on Contentnea Creek, on Tar River in the vicinity of Tarboro and on Roanoke River in the section above the State Farm.

In the better sections in which the formation is revealed, especially in the bluffs of Cape Fear River, the clay and sand are observed to form alternate strata from 2 to 10 feet or more in thickness, giving to the section a banded appearance, which is further emphasized by the difference in color, the clay being darker than the sand. In most places the sand layers show more or less cross-bedding, this feature being more strikingly developed, however, in exposures closely adjacent to the Piedmont border.

At but few places have the Patuxent strata been observed in actual contact with the basement rocks. Where seen, however, as might be predicted, pebbles and cobbles occur, and it may be presumed that practically everywhere along this contact a basal conglomerate of gravels is present.

The general strike of the beds, as may be inferred from the areal distribution of the belt of outcrop, is northeast-southwest.

The Cape Fear River bluffs furnish the only exposures of sufficient extent to permit of the determination of the approximate dip of the beds. No exact measurements were made, but from the fact that certain of the clay and sand layers can be traced for several miles, especially in the southern part of Cumberland County, approximately at right angles to the strike, with scarcely any appreciable change in the level, it is apparent that the dip in this region, at least, is very slight, being but little more than the grade of the stream itself. The disappearance of the formation beneath the overlying terrane appears to be due in part to an increase in the general slope of its upper unconformable surface, as well as to the dip of the beds themselves.

The thickness of the Patuxent formation from its upper surface to the underlying bedrock has been determined from well data at a number of places along the belt of outcrop. A well drilled by the Fayetteville Ice and Manufacturing Company, located at their plant on the Wicomico terrace on which the business part of Fayetteville stands,

with the exception of a few feet of Pleistocene materials at the top, penetrated this formation to a depth of 220 feet, at which depth ancient basement slate was encountered. An escarpment separating the Wicomico terrace from the Coharie terrace, whose elevation is about 100 feet greater than the Wicomico, runs north and south along the west border of the town. Poor exposures of Patuxent strata occur in this escarpment to a height of about 35 feet above the Wicomico terrace and are overlain by supposed Black Creek strata. The thickness in the vicinity of Fayetteville, therefore, amounts to about 255 feet. At Goldsboro, according to a section published by Darton,[36] about 175 feet of materials which should be referred to the Patuxent formation were passed through from 50 feet below the surface to the surface of the basement rocks underlying the Coastal Plain at 226 feet. At Tarboro in a well drilled under the auspices of the city government, basement rock was struck at a depth of 328 feet. The lower 228 feet of Coastal Plain materials is interpreted as referable to the Patuxent formation. In a deep well at Scotland Neck, Halifax County, basement rock was encountered at 349 feet below the surface, and it is believed that about 275 feet of Patuxent beds were penetrated. It thus appears that along the southeastern border of the belt of outcrop throughout its northeast-southwest extent the thickness is comparable to that at Fayetteville. In the coastward direction down the dip the formation may thicken somewhat for a short distance, but as the coast is approached it is believed to become thinner and finally to pinch entirely out between the underlying basement rocks and the overlying Upper Cretaceous beds.

The only data throwing light upon the presence or absence of the formation far out under the younger deposits of the Coastal Plain are furnished by two deep borings. One of these, located at Wilmington, reached a basal granite at a depth of 1,109 feet. Only Upper Cretaceous beds were penetrated, indicating that land, either an island or peninsula, existed in the Wilmington region during early Cretaceous time, and that either no Lower Cretaceous beds were deposited or, if such deposition took place, that the resulting beds were removed by erosion before the beginning of Upper Cretaceous deposition. The other well, located at Fort Caswell, at the mouth of Cape Fear River estuary, reached basement rock at a depth of 1,540 feet. There is some doubt as to the age of some of the lower beds penetrated, but there seem to be no certain grounds for regarding any portion of the section as representing Lower Cretaceous deposits.

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[36] U. S. Geol. Survey, Bull. No. 138, pp. 202-203.

No fossil remains have been found in the deposits of the Patuxent formation in North Carolina except small amounts of lignite in some of the exposures on Contentnea Creek, and on Tar and Roanoke rivers.

Detailed Sections.—The strata of this formation are best exposed in the bluffs of the streams which cross the belt, at all places where present, forming the base of the deposits of the Coastal Plain and rising to various heights above the level of the water to a maximum of 50 or 60 feet. A few good interstream localities have been observed.

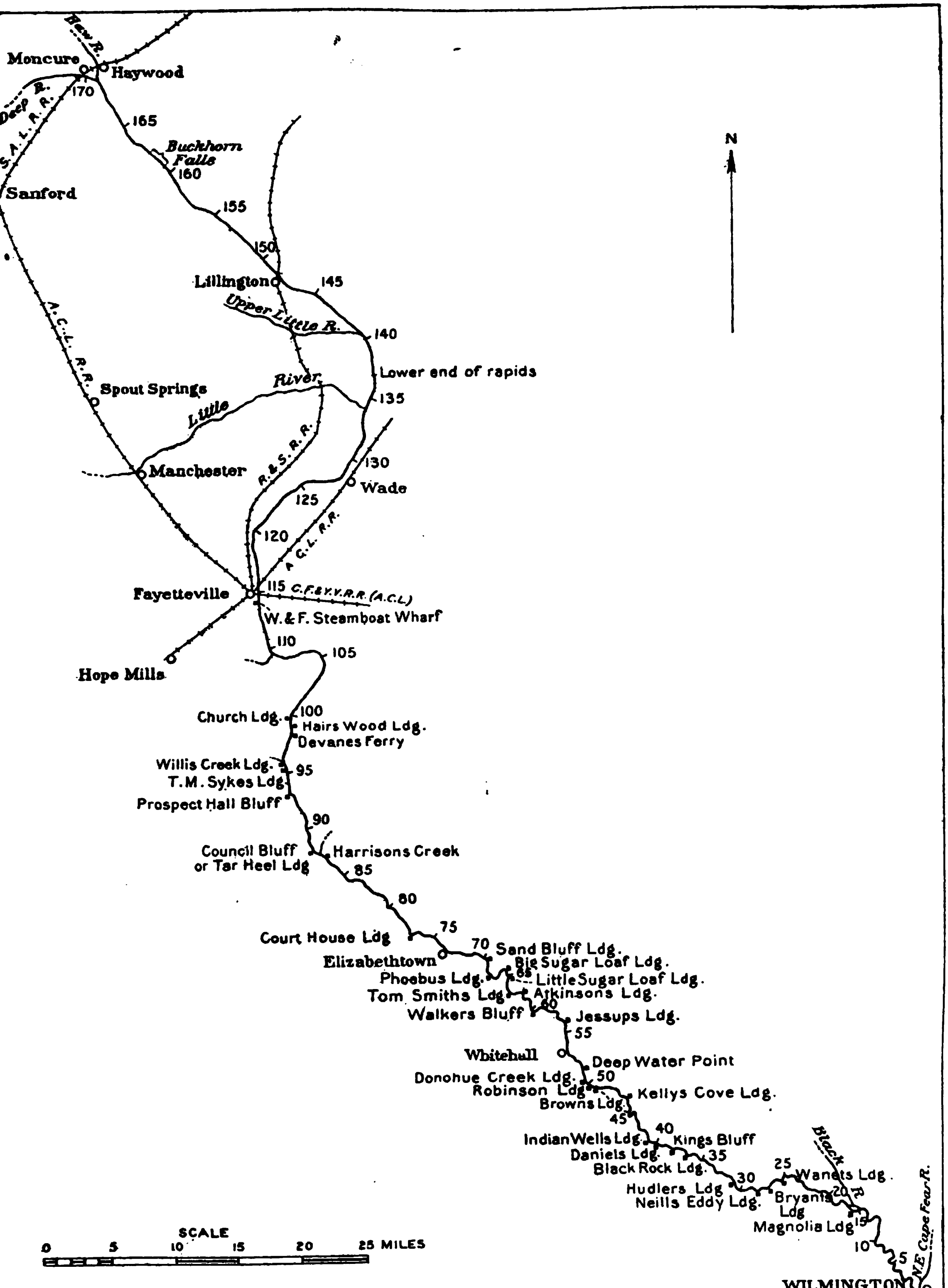
The most complete series of exposures are those appearing along Cape Fear River from a point about 1½ miles above the mouth of Little River in Harnett County, to Devanes Ferry, 17 miles below Fayetteville in Cumberland County. The sections in nearly all cases show at least 15 or 20 feet of Patuxent strata, and at a number of the bluffs the beds are revealed to heights of 50 feet or more above low-water level. For the greater part of this distance the overlying beds consist of Pleistocene terrace materials. Towards the southern limit of the line of exposures, however, between mileposts 100 and 101, the feather edge of the Black Creek ("Bladen") formation begins to appear, resting in basin-like depressions on the eroded surface of the Patuxent beds and overlain by the usual terrace deposits. In the next 3 miles the unconformable relations of the Patuxent and Black Creek beds are clearly exhibited in several sections. The former appears for the last time at Devanes Ferry, near milepost 98, where it finally passes from view beneath the latter. (For sketch map of Cape Fear River, see Plate I.)

The more important sections presented by the bluffs of this stream will be described in detail on the following pages. The fall line, that is, the foot of the last rapids formed by the basement rocks, is at a point about 2½ miles above the mouth of Little River in Harnett County. The first section observed in descending the river is at a point about 1 mile below the fall line and about 1½ miles above the mouth of Little River. It is as follows:

SECTION ON LEFT BANK OF CAPE FEAR RIVER 1½ MILES ABOVE THE MOUTH OF LITTLE RIVER.

Pleistocene:	FEET.
Surface loam	8
Light yellow, argillaceous sand	8-10
Gravel lens about 3 feet thick at middle of exposed portion of bluff, and thinning out towards each end in a distance of about 200 feet	0-3

(Unconformity.)



SKETCH MAP OF PART OF CAPE FEAR RIVER.

	Feet.
Cretaceous (Patuxent formation):	
Drab, iron-stained, sandy clay, grading down into coarse, gray, gravelly, arkosic sand, containing some mica	8
Hard, drab, iron-stained (yellow and red) sandy clay, becoming more sandy towards base and grading into next layer below	3-5
Greenish gray, arkosic, micaceous sand (very micaceous in places, especially towards base)	10
Dark greenish drab clay	4
Very hard, coarse, iron-stained, argillaceous sand	10
Yellowish drab clay, becoming sandy at top, mottled in places with dark-red iron stain	6
Concealed to water's edge by landslide	28-30

From this point to and beyond Fayetteville the present flood plain of the river is very narrow and in places almost absent. The steep banks formed by the partially indurated materials of the Patuxent formation, for the most part covered with vegetation, rise on either side to heights of 40 to 60 feet. The narrow flood plain, in most places not more than a few feet to a few rods in width, is present, as a rule, on one side of the channel only. At a few places the floods which have swept through the gorge have torn away the vegetation covering the steep slopes, revealing the outcropping Patuxent beds.

The next good exposure is at the mouth of Little River. The upper part of the bluff is terrace material continuous with that forming the terrace on which Fayetteville is built. The details of the section are as follows:

SECTION AT MOUTH OF LITTLE RIVER, RIGHT BANK.

	Feet.
Pleistocene:	
Reddish loam, grading down into hard, reddish sandy clay	6
Concealed by talus	10
Gravel band not well exposed, with large pebbles and cobbles and some large erratic bowlders 2 or more feet in diameter	2-3
(Unconformity.)	
Cretaceous (Patuxent formation):	
Yellow and drab, stratified, arkosic sand	2
Light drab, sandy clay, more sandy in the middle portion, mottled with dark-red and purple iron stain	5
Arkosic and micaceous sand, light gray to greenish gray, and more or less mottled with red and yellow, becoming very micaceous towards base	18
Greenish drab, sandy clay, mottled with dark red	4
Hard, greenish drab, arkosic and micaceous sand, becoming coarser at base, to water's edge	3

Near Wade, Cumberland County, a section is exposed on the left bank, as follows:

SECTION NEAR WADE, NORTH CAROLINA.

	FEET.
Pleistocene:	
Yellowish and gray sands with a thin gravel bed at base, containing in addition to rounded and angular quartz pebbles, erratic bowlders of igneous and metamorphic rocks of all sizes up to several feet in diameter	6
(Unconformity.)	
Cretaceous (Patuxent formation):	
Coarse, light-gray sand, slightly darker at the top, mottled with yellow, slightly stratified, and containing layers more or less argillaceous	6
Greenish-gray, crumbly or grainy clay, darker in top layer, and mottled throughout with dark-red streaks	8.5
Fine micaceous, greenish-gray clay	2-5
Dark gray, micaceous, arkosic sand, mottled with rusty streaks and slightly indurated	3.5
Greenish-gray, micaceous sand, mottled with red and yellow and softer and lighter in color than preceding	5.5
Greenish-gray, micaceous, arkosic sand, coarse to fine, indurated to a soft sandstone, making a steep cliff. It is somewhat mottled with reds and yellows	16
Yellowish-green, micaceous sand, fine in upper part, becoming coarse and strongly mottled with reds and yellows in lower half.	5
Greenish-gray, very micaceous, slightly arkosic sand to water's edge	3

In its lithologic character this section is essentially the same as the two preceding.

At Fayetteville a fairly good exposure occurs between the wagon bridge and the C. F. and Y. V. Railway bridge. As this is essentially the same as a better section occurring ¾ mile below at the Wilmington and Fayetteville steamboat wharf, the latter will be given in detail.

SECTION AT WILMINGTON AND FAYETTEVILLE STEAMBOAT WHARF, FAYETTEVILLE, N. C.

	FEET.
Pleistocene:	
Sand and loam with gravel band at base containing erratic bowlders of quartz and crystalline rocks	10
(Unconformity.)	
Cretaceous (Patuxent formation):	
Coarse gray, compact, argillaceous and arkosic sand with some mica and many small pebbles as large as peas. A yellowish band of iron crust, 1 to 2 inches thick, occurs along the base....	6
Hard, bluish-gray, coarsely arenaceous, micaceous, arkosic clay grading down into next layer below	2
Fine, yellowish, micaceous, somewhat arkosic iron-stained sand, with an iron crust layer ½ inch thick at base	5
Dark band of arenaceous clay, mottled with purple iron stain....	2

A.—Exposure of strata typical of the Patuxent formation, Cape Fear River, below the Wilmington and Fayetteville steamboat bridge, near Fayetteville, N C.

B.—Exposure of the Patuxent formation, Cape Fear River, about 10 miles below Fayetteville, N. C. Shows also the projections described on page 91.

Cretaceous (Patuxent formation):	FEET.
Hard, light-gray, coarse-grained, arkosic micaceous sand	6
Band of hard, dark gray, arenaceous, somewhat micaceous, arkosic clay, mottled with purple iron stain	3-5
Hard, gray, coarse, very arkosic micaceous sand, in places becoming coarser and containing many small quartz pebbles as large as peas	6-8
Drab to yellowish and red mottled clay, making a dark band along the cliff, becoming micaceous and sandy towards base	4-5
Hard, coarse, arkosic sand, somewhat micaceous	3
Dark, bluish-gray, argillaceous, very micaceous sand not well exposed, to water's edge	3

The distance by the river from Wilmington to Fayetteville is 115 miles. The mile intervals are indicated by numbers painted on boards and nailed to trees growing near the banks. The numbering begins at the former place and proceeds upstream to the latter.

For the first 4 or 5 miles below Fayetteville the river has a nearly straight course and the exposures are few and unimportant. At about milepost 110 the river makes a broad bend from its south-southeast course around to the east, south and southwest, coming back in line with its former course at about milepost 100. For a number of miles along the right bank of the northern limb of this bend and along the left bank after it turns to the south and southwest, the Patuxent beds are remarkably well exposed in bluffs ranging from 25 to 50 feet in height. The materials consist of layers of compact, partially indurated clays and arkosic and micaceous sands, from a few feet to 10 or 12 feet in thickness, making broad light and darker bands along the faces of the bluffs, the sections being similar in all essential respects to those farther up the river previously described. The beds are almost horizontal, it being possible to trace the bands along the bluffs for a number of miles without detecting any appreciable dip.

One of the striking features to be observed along the face of these bluffs is the effect produced by the water of the brooks and springs which enter the river through little overhanging valleys, on the sands and clays of the Patuxent formation over which it descends. It seems that these materials, kept constantly moistened, are rendered more resistant to the eroding effects of the high waters of the main stream than the adjacent materials of the same layers which are subjected to repeated wetting and drying so that the latter are cut away more rapidly, leaving the former standing out as rounded projections 4 or 5 feet in thickness at right angles to the face of the bluff, and from 10 to 25 feet or more in height. See Plate II, B.

The upper 10 to 15 feet in all these bluffs is made up of Pleistocene

sands and clays, in most places a gravel band containing erratic bowlders of quartz or crystalline rock being present at the base, the materials representing a continuation downstream of the terrace materials exposed at and above Fayetteville.

Between mileposts 100 and 101 beds of the Black Creek ("Bladen") formation begin to appear in the bluffs, occupying shallow basins in the eroded surface of the Patuxent beds and covered over by horizontal Pleistocene deposits. The relations of the different materials are roughly shown in Fig. 1.

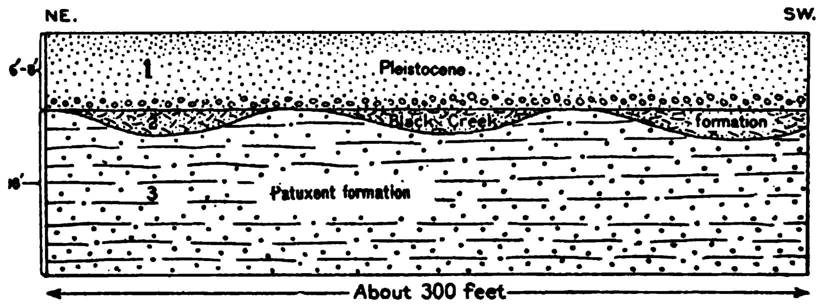


FIG. 1.—Sketch showing the relations of the Patuxent and Black Creek formations to each other and to overlying Pleistocene deposits; Cape Fear River, between mileposts 100 and 101.

The Patuxent materials represented in the section are of the usual character. In striking contrast to them are the materials occupying the basins, which consist of dark laminated sands and clays, in places containing considerable lignite, whose general aspect is the same as that of the materials of similar character which make up the bluffs farther down the river. They constitute the feather edge of the Black Creek ("Bladen") formation which overlies unconformably the Patuxent formation. This interpretation is confirmed by an observation made near Church Landing, right bank, about milepost 100. See Fig. 2.

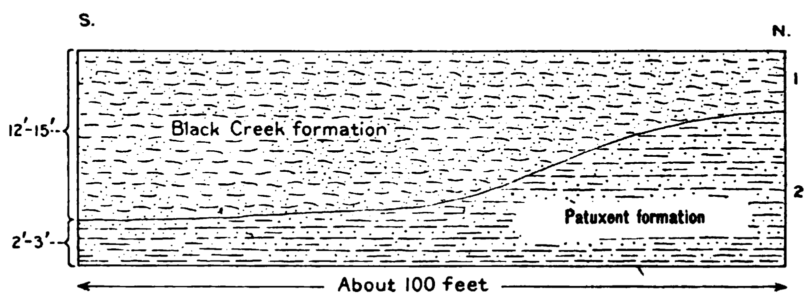


FIG. 2.—Sketch showing the relation of the Patuxent formation to the Black Creek formation near Church Landing, Cape Fear River.

Here there is a marked unconformity between the Patuxent formation, consisting of the usual compact, partially indurated, drab, sandy clays and light-gray, arkosic and micaceous sands, and the overlying laminated sands and clays of the Black Creek formation.

That the unconformable relations existing between the Patuxent and Black Creek formations are very marked is further proven by observations made at Hairs Wood Landing, ¼ mile below milepost 99. In a section extending for several hundred yards along the left bank the only materials seen are those belonging to the Patuxent formation and to the Pleistocene, the former consisting of the usual compact sands and clays rising some 20 or 25 feet above low-water level, and the latter consisting of characteristic sands and clays with a thin gravel band at base. The laminated materials of the Black Creek formation are entirely absent. At Devanes Ferry, however, just above milepost 98, left bank, the Black Creek beds are again seen resting unconformably upon the Patuxent beds. This is the last section in which the beds of this formation appear.

In Johnston County exposures of typical Patuxent strata occur in cuts of the Atlantic Coast Line Railroad in the vicinity of the village of Four Oaks. In one of these 4½ miles southwest of the depot sands and clays, with a line of quartz and schist fragments along the base, belonging to the Patuxent formation, were observed in contact with deeply decayed crystalline schists. This is one of the few places where the contact of the formation with the underlying basement rocks has been observed.

In a cut 5 miles southwest of Four Oaks the unconformable relation of the Patuxent, of the Lower Cretaceous, to the overlying Pleistocene is well exhibited. A similar exposure occurs in a cut 2¾ miles northeast of Four Oaks, as represented in the section (Fig. 3) on page 94.

Occasional exposures occur in Johnston County in the hills for several miles to the south and southeast of Four Oaks, and one good outcrop occurs about 2½ miles northwest of Four Oaks in the road leading from Black Creek up to Clements Church.

On Neuse River various exposures of the Patuxent formation occur from 1 mile above Cox's Bridge in Johnston County to the Atlantic Coast Line Railroad bridge southwest of Goldsboro in Wayne County. These occurrences are all low, the beds not rising more than 8 or 10 feet above extreme low water. Throughout this distance the Patuxent strata are overlain unconformably by overlapping beds of the Black Creek formation, except where the latter have been removed

SW NE.

15'

← About 1000 feet →

FIG. 3.—Sketch showing the relation of the Patuxent formation to the Coharie formation; in cut of Atlantic Coast Line Railroad, 2¾ miles northeast of Four Oaks, Johnston County, N. C. (near Corinth Church)

EXPLANATION OF SECTION.

Pleistocene:

1 and 2. Coarse, pebbly sand. (*Unconformity.*)

Patuxent formation:

3. Medium-grained micaceous, argillaceous, mealy textured sand, gray and yellow in color, with occasional red mottlings. Thin layers of light drab sandy clay occur in places along the top.

(*Unconformity probably local in character.*)

4. Dark to light drab, tough, massive clay.

by Pleistocene terracing processes. The Patuxent-Black Creek contact undulates a few feet above and below water level. (For sketch map of Neuse River, see Fig. 4, p. 96.)

From Smithfield to Blackman's Bluff the river is bordered by low Pleistocene terraces, and as the observations were made at a time when the water was 8 or 10 feet higher than its normal stage, none but Pleistocene materials were seen for this distance. Had the water been low it is probable that Cretaceous beds would have been revealed at the base of some of the sections.

At Blackman's Bluff 117½ miles above New Bern only Black Creek beds were exposed, but it is possible a low-water stage would have revealed Patuxent beds at the base.

All the remaining Neuse River sections described below were prepared from observations made at medium to low water stages.

At 115¾ miles above New Bern and 1 mile above Cox's Bridge, the following section occurs:

SECTION 1 MILE ABOVE COX'S BRIDGE, RIGHT BANK.

	Feet.
Pleistocene:	
Yellowish clay, becoming sandy towards base, containing occasional pebbles and small bowlders of quartz and crystalline rock, especially near the base, and also a few rather large pieces of silicified wood	10
Gravel band	½
(Unconformity.)	
Cretaceous (Patuxent formation):	
Dark gray, very compact, micaceous, arkosic sand	2

Coors Mill Branch enters from the left bank a short distance above milepost 111 and just above Quaker Bridge. Coors mill is located about ½ mile up this branch, just where it leaves the higher land to cross the river flood plain. The foundation of the mill is built upon a crystalline phyllite rock which was observed rising to a height of 10 feet above the bed of the stream, and, as indicated by the occurrence of large angular quartz fragments, a short distance away on a higher terrace level at a height of 30 or 40 feet above the stream bed, the basement rocks probably penetrate upward entirely through the deposits of the Coastal Plain at this place. This is interesting as showing the great unevenness of the buried Piedmont surface in this region.

At Tollers Bridge, milepost 106, there was exposed at low water about 3 feet of light-drab, finely arenaceous and micaceous clay, of the

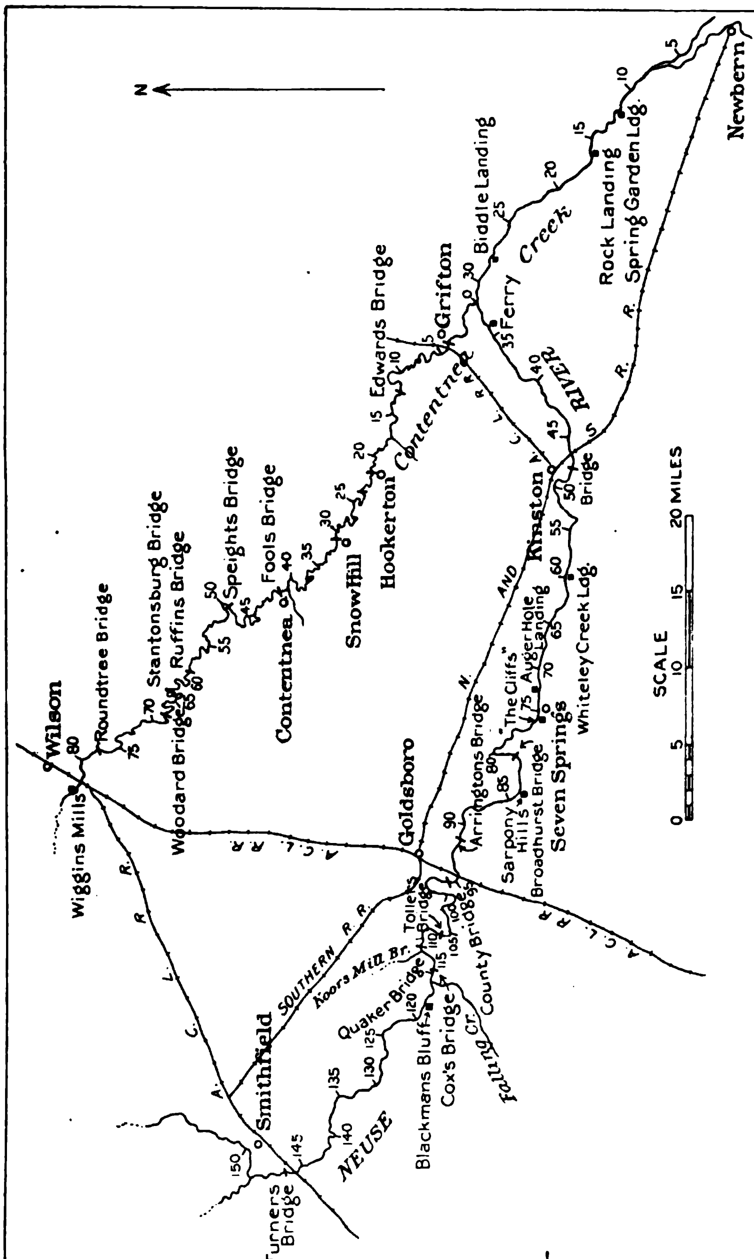


FIG. 4.—Sketch map of part of Neuse River and part of Contentnea Creek.

Patuxent formation, overlain by 10 feet of Pleistocene sand, with a band of gravel containing crystalline bowlders at base.

At milepost 105, the river cuts into the upland and an interesting section is revealed which shows the contact of the Patuxent and Black Creek formations. The relations of the formations exposed are shown graphically in Fig. 5.

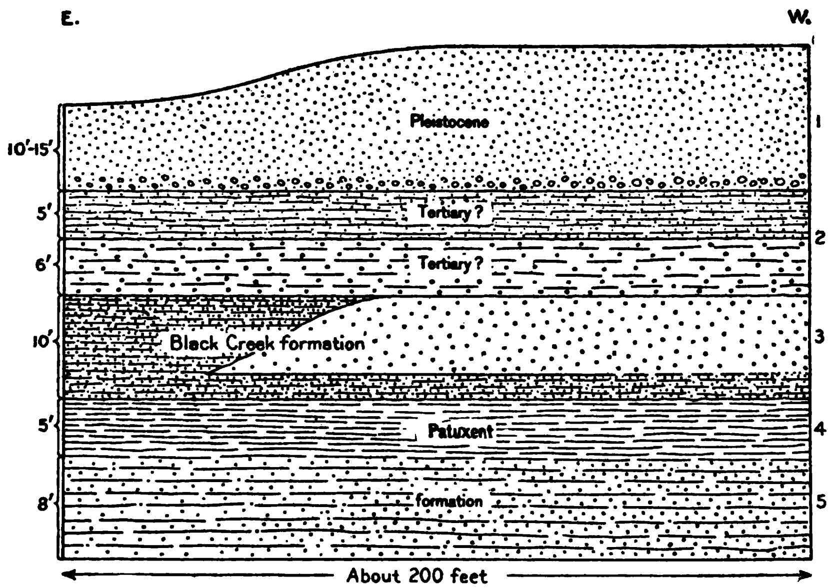


FIG. 5.—Sketch showing the relation of the Patuxent formation to the Black Creek formation, and the relation of the latter to post-Cretaceous deposits, Neuse River, milepost 105.

SECTION AT MILEPOST 105, RIGHT BANK.

Pleistocene:	FEET.
1. Coarse sand with gravel at base	10-15
(Unconformity.)	
Tertiary:	
2. Light-gray, micaceous sand, interstratified with thin layers of light-drab plastic clay and layers of clay pellets of the same nature, the sand in places indurated to an iron stone	6
(Unconformity.)	
Cretaceous:	
Black Creek formation:	
3. Dark drab, thinly laminated sandy clay with partings of fine micaceous sand, containing some small pieces of lignite. These materials are replaced in part a short distance away at the same level by a large lens of yellowish, stratified sand 7 or 8 feet in maximum thickness	10
(Unconformity.)	

Patuxent formation:	Feet.
4. Greenish gray, compact, arkosic, sandy clay, with irregular lenses of light-drab clay. The dark clay is filled with small dark particles which under the microscope appear to be partially decomposed marcassite..............................	5
5. Coarse, gray, compact arkosic, somewhat argillaceous sand....	8

Between the preceding locality and the county bridge none but Black Creek or supposed Black Creek beds are exposed in the river banks, the Patuxent-Black Creek contact being below water level.

At the county bridge, however, 2 miles southwest of Goldsboro and 94¾ miles above New Bern, right bank, the Patuxent beds again appear unconformably overlain by beds of the Black Creek formation, as shown in the following graphic section, Fig. 6. (See, also, Plate III, B.)

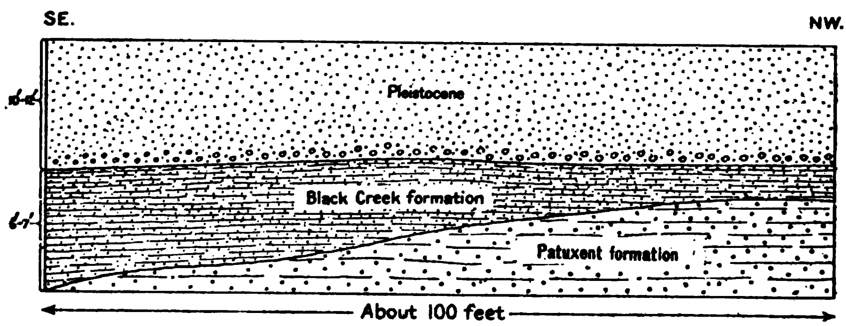


Fig. 6.—Sketch showing the relation of the Patuxent formation to the Black Creek formation, and of the latter to overlying Pleistocene deposits; Neuse River, at the county bridge, 2 miles southwest of Goldsboro, N. C.

Explanation of Section.

1. *Pleistocene.*—Yellow clay loam, grading down into coarse gravelly sand with gravel band at base, containing bowlders of crystalline rocks.
2. *Black Creek formation.*—Dark to black, laminated clay with partings and thin layers of fine micaceous, slightly glauconitic sand, the whole more or less lignitic and containing numerous concretions of iron sulphide. The lignite occurs in the form of large and small pieces and in seams of comminuted particles. Fragments of wood remains which resemble charred wood are present in considerable numbers.
3. *Patuxent formation.*—Very compact, drab clay and coarse arkosic micaceous sand.

The last appearance of the Patuxent formation above water level is at the A. C. L. R. R. bridge ¾ mile below the preceding, where the following section is exposed:

A.—Exposure of the Patuxent formation, Little River, one-half mile below the railroad bridge at Manchester, Cumberland County, N. C.

B.—Exposure on Neuse River at county bridge, two miles southwest of Goldsboro, N. C. Shows unconformable contact between the Patuxent and Black Creek formations.

SECTION AT A. C. L. R. R. BRIDGE A SHORT DISTANCE ABOVE MILEPOST 94, RIGHT BANK.

	Feet.
Pleistocene:	
Yellow clay loam	3
Yellow sand, becoming coarser towards base	7
Gravel band with pebbles and cobbles of all sizes up to 4 or 5 inches in diameter, and many pieces of silicified wood	1
(Unconformity.)	
Cretaceous:	
Black Creek formation:	
Laminated, cross-bedded, dark clay and gray micaceous sand, containing lignite and iron sulphide concretions	5
(Unconformity.)	
Patuxent formation:	
Compact drab clay	3

On Contentnea Creek there are occurrences of Patuxent strata from 1 mile above Woodard Bridge 8 miles south-southeast of Wilson, to within 1 mile of Contentnea in Greene County. These exposures are mostly low, at but few places rising more than 5 or 6 feet above the water, the maximum height being about 15 feet. Between the first exposure at the locality indicated and a point 2 miles below Speights Bridge the beds overlying the Patuxent formation are of Miocene age, except where the latter have been removed by Pleistocene terracing processes. The low terrace sections reveal either Pleistocene deposits overlying Patuxent beds or Pleistocene beds only. From the locality 2 miles below Speights Bridge to the last exposure of the Patuxent formation near Contentnea the sections are all cut in the lowest Pleistocene terrace, and reveal at their base either Patuxent beds alone, or Patuxent beds overlain unconformably by Black Creek beds, or Black Creek beds only. The undulating contact rises and falls above and below the water level in such a manner as to reveal one or the other or both of the formations, the Patuxent, however, finally passing beneath the overlapping Black Creek beds about 1 mile above Contentnea. (For sketch map of Contentnea Creek, see Fig. 4, p. 96.)

A detailed account of the Contentnea Creek exposures is given below.

The first appearance of the Patuxent formation is at a point about 1 mile above Woodard Bridge, Wilson quadrangle, the section being as follows:

SECTION 1 MILE ABOVE WOODARD BRIDGE, RIGHT BANK.

	Feet.
Concealed, but in part Pleistocene and in part Miocene	20-25
Miocene:	
Dark drab clay, with soft casts. Pebble band at base	2
(Unconformity.)	

Cretaceous (Patuxent formation):	FEET.
Very compact, light gray, micaceous, arkosic sand...............	15

Between this locality and Ruffins Bridge on the same quadrangle the Patuxent materials are revealed in low exposures not exceeding 6 or 7 feet, on the one side of many of the bends. They are everywhere characterized by their compact, partially indurated condition, and consist of light gray, micaceous, arkosic sands, or drab micaceous clays. A log of lignite 8 inches in diameter was observed in the materials at one place. The beds are in most places overlain by 8 to 10 feet of loam and sand with a band of gravel at base, as a rule containing bowlders of crystalline rocks and small pieces of silicified wood, which constitute Pleistocene terrace deposits.

One-half mile above Speights Bridge, Wilson quadrangle, the following observations were made:

SECTION ½ MILE ABOVE SPEIGHTS BRIDGE, LEFT BANK.

	FEET.
Concealed by vegetation..	12
Pleistocene:	
Mostly concealed, but consisting partly of sand with a band of gravel at base...	12-15
(Unconformity.)	
Miocene:	
Sand and clay...	9
(Unconformity.)	
Cretaceous (Patuxent formation):	
Very compact drab, sandy, micaceous clay......................	4
Very compact gray, micaceous, argillaceous, arkosic sand........	6

A bluff at Speights Bridge exposes only Miocene strata, the Patuxent surface being below water-level.

In the next 1½ miles Patuxent beds were seen at several places rising 4 or 5 feet.

About 2 miles below Speights Bridge, right bank, Wilson quadrangle, in a distance of several hundred yards the surface of the Patuxent beds rises and falls 4 or 5 feet above and below water-level, being overlain unconformably by dark drab to black laminated clays with partings of fine micaceous sand, containing much lignite in small pieces and comminuted vegetable remains. The laminated beds belong to the Black Creek ("Bladen") formation. For the next few miles, to within 1 mile of Fools Bridge (Contentnea P. O.), Falkland quadrangle, the Patuxent beds, consisting of the usual compact light drab

clays and light gray, arkosic sands, are exposed at many places along the cove sides of the river bends and are in most places overlain by 6 to 10 feet of Pleistocene terrace deposits. Beyond the point indicated there are no more surface exposures of the Patuxent formation.

Tar River exhibits the beds of the formation from a point about 4 miles below Dunbar Bridge in Edgecombe County to Parker Landing in Pitt County. Above Tarboro the occurrences are all low, as a rule less than 6 feet being revealed; while below this town the surface of the formation gradually rises to a maximum height of 16 or 18 feet near Penny Hill in Pitt County. (See sketch map of Tar River, Fig. 7.)

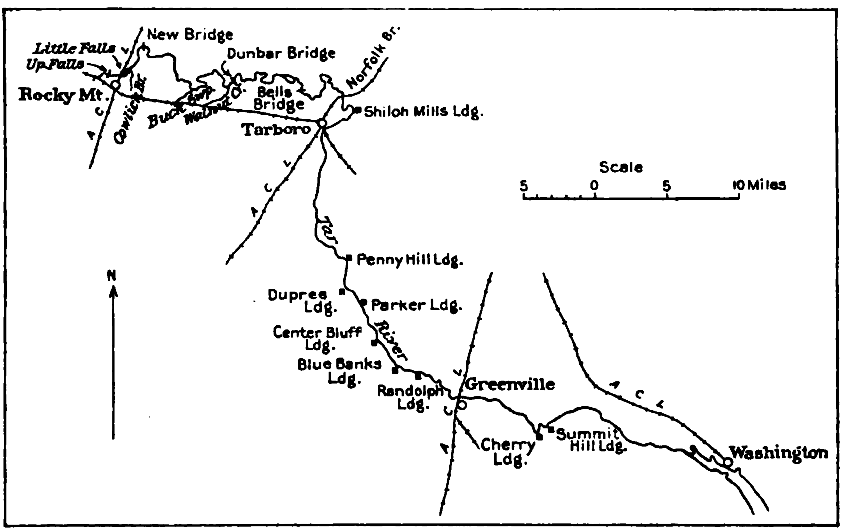


FIG. 7.—Sketch map of part of Tar River, N. C.

From its first appearance in Edgecombe County to a point about ¼ mile above Parker Landing the formation is overlain either by beds of Miocene age or by Pleistocene terrace deposits. At the last point indicated, however, and also a short distance below Parker Landing, the Black Creek formation appears resting unconformably upon the Patuxent formation. Beyond this the latter does not again appear, having passed finally from view beneath the water level.

The Tar River occurrences are described in detail on the following pages.

SECTION ABOUT 4 MILES BELOW DUNBAR BRIDGE, LEFT BANK.

Pleistocene:	FEET.
Yellowish loam and sand, becoming coarse and gravelly towards base	10-12

(Unconformity.)

	FEET.
Miocene:	
Greenish gravelly sand	1-3
(Unconformity.)	
Cretaceous (Patuxent formation):	
Light gray, coarse, compact, argillaceous, very arkosic sand	1-3

For the next few miles to within ½ mile of Hemmed Island there are numerous low exposures in places showing only the compact arkosic sands or drab clays of the Patuxent formation overlain by 10 or 12 feet of Pleistocene, at other places showing only the Miocene in a similar relation to the Pleistocene, and at still other places showing a few feet of the Miocene resting on the undulating surface of the Patuxent and overlain by the Pleistocene.

The next place at which Patuxent strata were observed was at a point about 2 miles below the A. C. L. (Norfolk branch) Railroad bridge, where 4 feet of very compact, laminated, drab clay and gray sand is exposed above medium low-water level.

At Shiloh Mills, left bank, Parmele quadrangle, 2½ miles above Tarboro, Miocene shell marl rests directly upon the undulating surface of the Patuxent, the latter varying in height within the limits of the exposure from 3½ to 5 feet above medium low-water stage. The Patuxent materials consist of greenish gray, sandy, very micaceous, very compact clay.

Between Shiloh Mills and Tarboro, Tarboro quadrangle, the Patuxent beds appear in a number of low exposures not exceeding 8 feet in height, consisting of characteristic arkosic, micaceous sands and drab clays. In places the sand is cross-bedded, though everywhere compact, and at one place a large flattened log and other small pieces and particles of lignite were observed.

Similar occurrences continue at occasional intervals below Tarboro. In a few places shell marl or a pebbly conglomerate with a matrix of greenish sand belonging to the Miocene were seen occupying shallow basin-like depressions in the surface of the Patuxent beds, and overlain by 8 to 10 feet of Pleistocene terrace deposit. In some of the better sections the Patuxent beds assume a banded appearance due to the alternating strata of sand and clay, in this respect resembling sections of the same formation exposed along Cape Fear River. The best and highest section of this kind on the Tar River occurs a short distance below Penny Hill, Tarboro quadrangle, as follows:

SECTION BELOW PENNY HILL, LEFT BANK.

	FEET.
Pleistocene:	
Loam and sand with gravel band at base	5-6
(Unconformity.)	
Miocene:	
Thin seam of loose greenish sand	3 in.
(Unconformity.)	
Cretaceous (Patuxent formation):	
Very compact, drab, sandy clay, slightly iron-stained	6
Compact, grayish-drab, micaceous, argillaceous sand	2
Compact, gray, micaceous, arkosic sand, stained yellow in places	2
Compact, drab, micaceous, arenaceous clay stained with iron	2
Compact, drab, micaceous, arkosic, argillaceous sand	4

At Dupree Landing, Falkland quadrangle, the Patuxent beds appear a few feet above the water, and again above and below Parker Landing, Winterville quadrangle. About one-fourth mile above Parker Landing the following interesting section was taken:

SECTION ABOVE PARKER LANDING LEFT BANK.

	FEET.
Pleistocene:	
Yellow sand, becoming coarse and cross-bedded at base	7
(Unconformity.)	
Cretaceous:	
Black Creek formation:	
Dark to black, laminated, micaceous, sulphur-stained clay with partings of fine micaceous sand, containing lignite and iron sulphide concretions. This deposit appears to occupy a depression in the surface of the Patuxent formation, although the relations are not very clear	0-6
(Unconformity.)	
Patuxent formation:	
Gray, arkosic, micaceous sand, compact in places, and loose, stratified, and iron-stained in others, containing occasional pieces and seams of lignite	5-10
Dark drab, compact, slightly micaceous arenaceous clay, irregular in exposed thickness along base of bluff	0-3

About 1/8 mile below Parker Landing the Patuxent formation makes its last appearance on Tar River, a few feet of compact drab clay being revealed at low water, overlain by several feet of laminated sand and clay of the Black Creek formation, the latter containing characteristic Black Creek plant remains (see description, p. 142.)

The following section of a well at Tarboro which was drilled under the auspices of the city government, by the Sydnor Pump and Well Company, of Richmond, Virginia, was made from a record furnished by John A. Weddell, Treasurer of the Board of Public Works of that city:

SECTION OF WELL AT TARBORO, N. C.

(ELEVATION AT SURFACE ABOUT 50 FEET.)

	Thickness in Feet.
Pleistocene:	
White sand	0- 15
Miocene (?):	
Caving sand	15- 25
Sandy clay	25- 40
Caving white sand	40- 65
Cretaceous (Patuxent formation):	
Stiff clay, bluish	65- 73
Yellow sandy clay	73- 85
White sand	85- 90
White stiff clay	90- 95
Blood-red clay and slate	95-105
White and pink sandy clay	105-115
White, coarse sand, with a little water	115-125
Yellow sandy clay	125-128
Yellow sand	128-132
Yellow clay	132-135
Red clay	135-145
Stiff yellow clay	145-150
Yellow sandy clay	150-152
Stiff yellow clay	152-160
Stiff red clay	160-170
Yellow sandy clay	170-174
Sandy clay and coarse gravel	174-182
Coarse sand, little water	182-190
Stiff yellow clay	190-194
Sandy yellow clay	194-196
Coarse sand	196-199
Stiff bluish and red clay	199-202
Stiff clay, red, yellow and white	202-212
Stiff blue clay	212-218
Stiff red and blue clay	218-228
Stiff brown clay	228-236
Stiff dark-brown clay	236-244
Stiff red clay	244-252
Red, black, and tan (clay?)	252-253
Yellow sand	253-256
Quicksand	256-257
Yellow clay	257-261
Blue clay	261-273
Red clay	273-277
Pink, red, and yellow clay	277-278
Quicksand	278-282
Marl, rock	282-284
Blue stiff clay	284-290

	Thickness in Feet.
Cretaceous (Patuxent formation):	
Hard red clay	290-300
Red sandstone	300-303
Hard red clay	303-305
Dark clay	305-311
Dark clay and gravel, rotten rock	311-321
Dark clay and gravel mixed	321-328
Basement rocks:	
Dark clay, like rotten soapstone	328-332
Tan clay	332-334
Rock formation	334-338
Tan clay	338-340
Hard clay and gravel?	340-343
Dark rock formation	343-346
Hard clay and gravel (?) mixed	346-349
Hard sandstone	349

The section shows a thickness of at least 288 feet of the Patuxent formation. Basement rocks were penetrated in the bottom of the well. From the descriptions of the materials as given in the driller's records the exact depth at which these were entered cannot be determined with certainty; but from correspondence with the town authorities it was ascertained that about the lower 20 feet of the well was drilled in supposed "bed rock," and it is probable that the material described as resembling "rotten soapstone" forms the upper decomposed portion of these older rocks.

The most northerly occurrences of Patuxent strata thus far observed are on Roanoke River from a point 5 miles below Halifax, near the State Farm, to the steamboat landing at Palmyra. Here, also, the exposures are all low, nowhere exhibiting more than about 12 feet of strata. With the exception of Pleistocene terrace beds, the overlying younger strata are everywhere of Miocene age. The Black Creek formation does not appear on this stream. The river was traversed from Weldon in Halifax County to Plymouth in Washington County. (See sketch map of Roanoke River, Fig. 8, p. 106.)

A search was made for the supposed Potomac deposit described by Fontaine in a section at the north end of the railroad bridge at Weldon, but the only materials exposed were of Pleistocene age, the basal beds apparently having been concealed by talus material subsequent to his visit. A study of the region about Weldon and Halifax, however, led to the conclusion that the existence of a Potomac equivalent at

this point is improbable, although it is possible that a feather edge of the Patuxent formation is present this far inland.

The bed of the river at Weldon exposes crystalline rocks. The rapids a short distance below the bridge may be regarded as the "fall line," although the crystallines appear at one or two places along the river banks between Weldon and Halifax landing, and at the latter

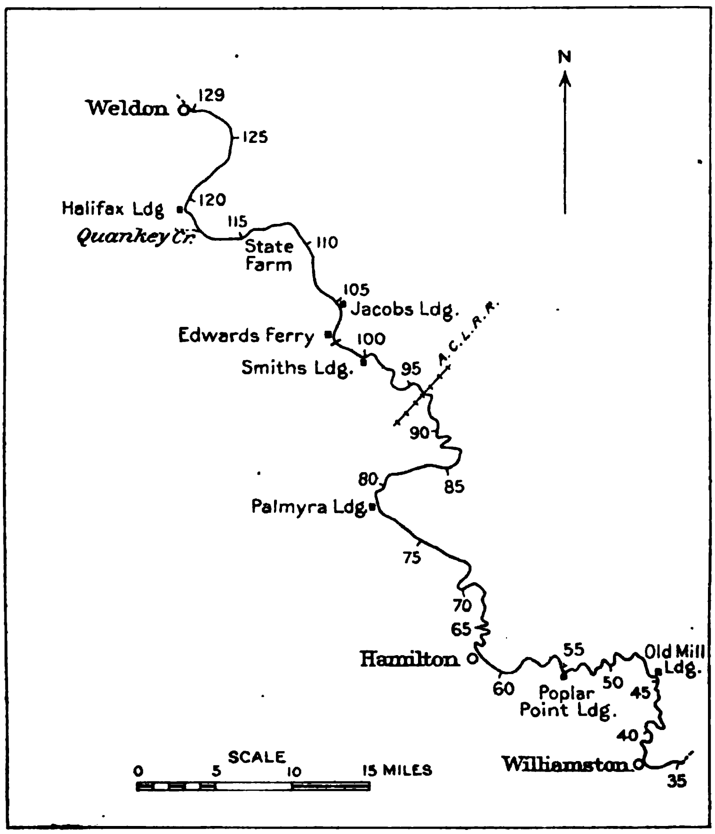


FIG. 8.—Sketch map of part of Roanoke River, N. C.

place a decayed granite rock cut by basic and acidic dikes is exposed to a height of 20 or 25 feet above low-water level. In the ravines south and southwest of Halifax along Quankey Creek there are good exposures of Miocene strata resting upon a decayed granite rock, and at a number of places Miocene shell marl occupies the base of the sections in direct contact with the granite. There seems to be an entire absence of Patuxent beds in the immediate vicinity of Halifax.

The first river section presenting beds of Potomac equivalence is at a point 5 miles below Halifax, a short distance above the State Farm. Where best exposed, the section is as follows:

SECTION 114¼ MILES ABOVE MOUTH OF RIVER AND A SHORT DISTANCE ABOVE THE STATE FARM, RIGHT BANK.

	Feet.
Pleistocene:	
Yellowish sandy clay loam	10
Coarse, yellow sand, in some layers gravelly, alternating with finer argillaceous sand layers	6
Heavy bed of gravel consisting of pebbles and cobbles and an occasional quartz bowlder	6
(Unconformity.)	
Miocene:	
Dark green clay with a few casts. At one place chunks of Patuxent material were observed reworked in the base of the Miocene	3-3½
(Unconformity.)	
Cretaceous (Patuxent formation):	
Very coarse, very arkosic and micaceous sand, becoming coarser and containing thin gravel layers and lenses towards the base	12

In an exposure a few hundred yards above where the section was taken the Patuxent-Miocene contact is only 4 feet above the water level, which indicates a considerable unevenness in the eroded Patuxent surface. The sand of the Patuxent formation here contains seams of lignite, and some larger pieces of brown lignite.

The next section showing unquestioned Patuxent materials is at Jacobs Landing, as follows:

SECTION AT JACOBS LANDING, MILEPOST 105, LEFT BANK.

	Feet.
Pleistocene:	
Partly concealed, sandy loam in upper 6 feet and layer of gravel at base	15
(Unconformity.)	
Cretaceous (Patuxent formation):	
Compact, dark to light gray, coarse micaceous, more or less arkosic sand. Contains some very large mica flakes	6

At Edwards Ferry the Patuxent is again exposed in unconformable relation to the overlying Miocene. The section is very similar to that near the State Farm.

SECTION AT EDWARDS FERRY, 102¼ MILES ABOVE MOUTH, RIGHT BANK.

	Feet.
Pleistocene:	
Concealed except for gravel band along base, which contains, in addition to pebbles, some large quartz and crystalline bowlders.	18-20

Miocene:	FEET.
Dark green clay with a few casts. At base a thin line of small pebbles lies along the small but sharply defined minor irregularities of the undulating contact. At one place chunks of Patuxent material were found reworked in the base of the Miocene...	0-4
(Unconformity.)	
Cretaceous (Patuxent formation):	
Lenses of light drab, micaceous, arkosic sand and drab to very light drab clay, both very compact and in places indurated almost to a hard rock. In places numerous specks of iron pyrites were observed	4-8

At J. N. Smith's Landing, milepost 100, right bank, 6 feet of typical Patuxent sand and clay are exposed, overlain by 10 to 15 feet of Pleistocene terrace materials, the Miocene being entirely absent.

The last point on the river where the Patuxent formation is exposed is in the 75-foot bluff at Palmyra Landing, 79½ miles above the river's mouth.

At the base of this section, immediately below a bed of Miocene shell marl, there appears 3½ feet of very compact, dark greenish-gray, sandy clay, containing in places fine grains of iron pyrites. Along the base of the overlying marl bed and corresponding to a basal conglomerate there is present a line of quartz and phosphate pebbles up to 2 inches in diameter and an occasional broken piece of bone. Below Palmyra the river bluffs expose no materials older than Miocene.

South of Cape Fear River a number of stream and interstream localities revealing beds of the Patuxent formation have been studied. Particularly good exposures are presented by the railroad cuts in the sandhills of Harnett, Moore, and Richmond counties.

At Spout Springs, Harnett County, in cuts of the Cape Fear and Yadkin Valley Railway (A. C. L.) north and south of the station there are good exposures of compact, massive, purplish clay of the Patuxent formation overlain unconformably by arkosic sands.

The purplish clay was regarded by Professor Kerr and others as belonging to the Eocene and by Professor Ward as belonging to the Tuscaloosa formation. It resembles closely the clays of the Patuxent formation, however, and should probably be referred to that division.

Similar exposures occur in certain of the cuts to the north of Spout Springs for 3 or 4 miles, some of the cuts, however, showing only the sands of the Lafayette formation. Likewise, to the south of Spout Springs similar clays are met with in cuts to and beyond Manchester in Cumberland County.

Patuxent beds essentially the same as those described in the section on Cape Fear River at the mouth of Little River (see p. 89) are exposed along the banks of Little River at Manchester and for 1 mile below the railroad bridge to the first wagon bridge. Observations were not carried down the river beyond this point. The best section observed, exposing about 30 feet of strata, was on the left bank about ½ mile below the railroad bridge. The materials consist of compact, in places slightly indurated, arkosic, micaceous sands and sandy clays, more or less mottled with red or purple iron stain.

Exposures of the formation occur in cuts of the Seaboard Air Line Railway in southeastern Moore County, beginning near Crane Creek bridge, where they rest upon basement rocks and extending southwestward. They are here overlain with a marked unconformity by discontinuous patches of surficial Lafayette sands. The unconformable relations of the Patuxent and Lafayette formations are clearly exhibited in a cut 1⅓ miles southwest of the station at Lâkeview, N. C. These relations are represented graphically in the following sketch, Fig. 9 (see, also, Plate XV, B, opposite p. 264):

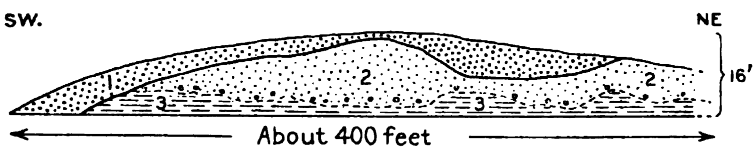


FIG. 9.—Sketch showing relation of the Patuxent formation to the Lafayette formation; cut of Seaboard Air Line Railway 1 1-3 miles southwest of Lakeview, N. C.

EXPLANATION OF SKETCH.

Lafayette formation:

1. Coarse, yellow, pebbly sand.

(*Unconformity.*)

Patuxent formation:

2. Partially indurated, medium to coarse, light gray, arkosic, micaceous sand, with a few small, angular pebbles along base.

(*Local unconformity.*)

3. Compact, coarsely arenaceous clay, dark drab to chocolate colored, with pink mottling, locally indurated to form a claystone.

In Richmond County, in the vicinity of Hamlet, good exposures occur in cuts of the S. A. L. Railway northwestward toward Rockingham for 2 miles, southeastward towards Old Hundred for 3 miles, south-southeastward at several places on the Gibson Branch, and southwestward on the main line at a number of places between Hamlet and Cheraw, S. C. The materials of the Patuxent formation in this

vicinity consist of light gray, coarse, arkosic sand, cross-bedded in places, and quite compact or even indurated to a hard rock, and of lenses of light drab or mottled red or purple, more or less finely siliceous, to coarsely sandy clay intercalated within the predominating sand mass. Here, also, discontinuous patches of Lafayette deposits are present upon the eroded Patuxent surface.

Outside of the sandhill country, perhaps the best exposures south of the Cape Fear are those in the vicinity of Hope Mills in Cumberland County.

One mile northeast of Hope Mills on the main line of the Atlantic Coast Line Railroad and to the north of Little Rockfish Creek, an interesting section is revealed at the south end of a long cut. The character and relations of the materials are shown in Fig. 10.

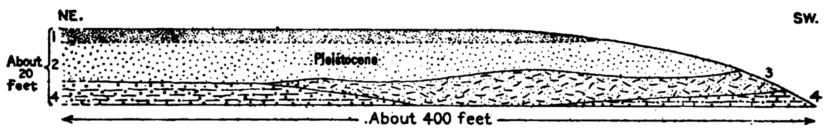


FIG. 10.—Sketch showing the relations of the Patuxent and Black Creek formations to each other, and to overlying Pleistocene deposits; cut of Atlantic Coast Line Railroad 1 mile northeast of Hope Mills, N. C.

EXPLANATION OF SKETCH.

Pleistocene:

1 and 2. Loose sand, becoming gravelly at base.

(*Unconformity.*)

3. *Black Creek formation:* Dark clays and stratified and cross-bedded sands containing lignite in considerable amount, and concretions of iron sulphide. The materials vary considerably in a short distance, in places being thinly laminated, with fine sand partings, and elsewhere presenting lenses of cross-bedded sand and thicker clay layers.

(*Unconformity.*)

4. *Patuxent formation:* Near the center of the cut, compact, coarse, gray, arkosic sand with rounded pellets of pure white clay, and towards the southwest end of the homogeneous plastic, drab clay.

Layer 3 is the feather edge of the Black Creek ("Bladen") formation occupying a position between the eroded surface of the Patuxent formation beneath, layer 4, and Pleistocene terrace materials above, layers 1 and 2.

Good sections of Patuxent strata similar in all respects to those occurring along Cape Fear River in the vicinity of Fayetteville are exposed on Little and Big Rockfish creeks both above and below the bridge of the road leading from Fayetteville to Hope Mills. In some of these a feather edge of the Black Creek formation occurs resting upon the Patuxent and overlain by Pleistocene terrace deposits. Detailed sections are given below. (See, also, section p. 116.)

SECTION 1 MILE SOUTH OF HOPE MILLS ON RIGHT BANK OF BIG ROCKFISH CREEK.

	Feet.
Pleistocene:	
Yellow sand, stratified, and containing a few clay layers at base..	9
Cretaceous:	
Black Creek formation:	
Tough, chocolate-tinted, carbonaceous clay with some lignite and vegetable particles	0-3
(Unconformity.)	
Patuxent formation:	
Gray, arkosic sand and clay	24-27

SECTION BELOW WAGON BRIDGE OVER ROCKFISH CREEK, NEAR BRUNT POST-OFFICE.

	Feet.
Pleistocene:	
Sand and gravel	5
(Unconformity.)	
Cretaceous (Patuxent formation):	
Compact, light gray and greenish gray, micaceous, arkosic sand and clay, in places slightly indurated and in places cross-bedded.	40

One doubtful Patuxent exposure has been observed on Lumber River in Robeson County, just below Redbank bridge. It is described as follows:

SECTION JUST BELOW REDBANK BRIDGE, LEFT BANK.

	Feet.
Cretaceous? (Patuxent formation?):	
Yellowish-brown, loamy, arkosic sand	4
Coarse, gray, compact, arkosic sand	6
Light drab, compact, sandy clay, becoming more sandy to a coarse, argillaceous sand at base	3
Very light drab, compact, slightly sandy clay	2

The materials in this section are not very characteristic, but it seems probable from their compact condition and the presence of arkosic matter that they should be correlated with the Patuxent formation.

UPPER CRETACEOUS.

BLACK CREEK FORMATION.

Name.—The name Black Creek was proposed by Mr. Earle Sloan in 1907.[1] It is derived from Black Creek, a tributary of Great Peedee River in Darlington and Florence counties, South Carolina.

The terrane to which he applied the name is the equivalent, as shown by both its lithologic and paleontologic characters, of the division in

[1]Handbook of South Carolina, issued by the State Department of Agriculture, Commerce and Immigration, 1907. Chapter 5, pp. 77–145. (This chapter is said by Watson to have been issued as a separate in May or June, 1907, and a map was published in 1905 on which the name Black Creek shale was used.)

North Carolina designated by the writer in 1907 the "Bladen" formation.[1] Since it appears that Sloan's usage has priority, it is given precedence in this report.

Belt of Outcrop.—The belt of outcrop of the Black Creek ("Bladen") formation occupies a position southeast of that described for the Patuxent formation. In the Cape Fear River region this belt has a width of some 30 or more miles, but it narrows to the northeast, the formation being exposed on Tar River, where the width amounts to about 8 miles. See geologic map, Plate XVII, in pocket.

Beginning at the northeast, the counties in which outcrops may be expected to occur are as follows: northern Pitt, northern Greene, Wayne, northwestern Duplin, Sampson, southern Cumberland, Bladen, and Robeson. In South Carolina the southward extension of the formation has been recognized along Black Creek in Florence and Darlington counties as far upstream as Darlington and at several other places in the eastern part of Darlington County, where it has been designated Black Creek shale, as explained in a preceding paragraph.

The beds of the Black Creek formation rest with a marked unconformity upon the eroded surface of the Patuxent formation. The contact is well exposed at various places on the Cape Fear and Neuse rivers, Contentnea Creek and Tar River. The time interval represented by this break is believed to have been of considerable duration, possibly as great as that included between the top of the Patuxent and the base of the Magothy in Maryland.

No structural break occurs between the Black Creek and Peedee ("Burches Ferry") formations, the character of the sediments indicating a transition from the shallower water conditions of the former to the deeper water conditions of the latter. The line of division between the two formations has been somewhat arbitrarily drawn at the top of the transition beds, or at the point where the materials become finally of a true marine character. The placing of the dividing line in this position has, however, been actuated in part by certain paleontologic considerations explained elsewhere in this report.

The formation extends coastward conformably beneath the overlying Peedee formation and has been recognized in the basal portion of a well boring at Wilmington, where the thickness amounts to about 390 feet, and also in the basal portion of a boring at Fort Caswell, where the thickness, if correctly interpreted, is 400 feet.

The beveled edge of the Black Creek formation in the belt where it would otherwise appear as the surface material is everywhere con-

[1] Johns Hopkins University Circular No. 7 (whole No. 199), July, 1907, pp. 93–99.

cealed from view by relatively thin overlapping Tertiary strata or by surficial Pleistocene terrace deposits, except as revealed by stream or artificial cuttings.

The Pleistocene deposits occur as a surficial covering of both the Tertiary and Cretaceous throughout the entire length of the belt. Except for certain Eocene occurrences in southern Wayne County and a number of Miocene occurrences in the vicinity of Elizabethtown and in southern Robeson County which probably exist as more or less detached basins on the surface of the Black Creek formation, the Pleistocene covering rests directly upon the Black Creek formation from Neuse River southward to the South Carolina State line. From northeastern Wayne County to the northern limit of the belt Miocene beds everywhere intervene between the Pleistocene terrace covering and the Black Creek formation, except along the stream borders, where in the process of formation of the lower terraces the Miocene beds were in places entirely removed.

The mass of the materials of this formation consist of thinly laminated, more or less ferruginous sands and clays. The character of the materials may vary abruptly, however, both horizontally and vertically, in some places the sand and at other places the clay predominating. At a number of places the clay has been observed to be replaced in a short distance horizontally by great lenses of medium-grained, highly cross-bedded sand. Not uncommonly the clay and sand laminæ are tipped at considerable angles from the horizontal, this position being due to current bedding. (See Plate V, B, opposite p. 120.) The clays are, as a rule, dark to black, due to the presence of carbonaceous matter, which explains the usual dark appearance of the exposures. The sands are commonly gray or light yellow, but may have a greenish tinge due to the presence of ferrous iron, or a slight content of glauconite. They are, as a rule, fine to medium grained in texture and almost universally contain a noticeable percentage of very fine flakes of muscovite mica. Thin lignite seams, consisting of finely comminuted vegetable particles, are very common. Pieces of lignite varying in size from small particles to that of twigs, branches, and even large trunks of trees, occur scattered irregularly through the materials of the formation. The larger pieces are in most cases flattened, but as a rule show the structure of the wood distinctly. Many of the smaller pieces appear water-worn, having their edges and ends rounded. Leaves have been found at many localities in a fairly good state of preservation, but in most cases they appear to have been subjected to maceration processes. Iron sulphide is in many places associated with the lignite, probably, as a rule, in

the form of marcasite, although possibly in some instances in the form of pyrite. This is found coating the lignite or filling the seams and cracks within the structure of the wood itself, and also in the form of irregular concretions of various sizes, not, as a rule, attaining very large dimensions. The surface which in the original position in the beds was covered with crystals of the mineral, is commonly corroded and rusty, as a result of exposure to the atmosphere. Amber has been observed at many places in the form of small particles not exceeding one-half inch in longest dimension.

Toward the upper part of the formation the laminated sands and clays become interstratified to greater or lesser extent with layers or lenses of greensand or marine clay. Likewise in the laminated portions themselves the thin sand partings and layers are noticeably glauconitic in places. These glauconitic beds constitute the transition deposits marking the passage from the more typical Black Creek formation into the greensands of the overlying Peedee formation.

The strike of the beds of this formation is approximately parallel to that of the Patuxent formation—that is, northeast-southwest.

On account of the cross-bedding and horizontal variation in the character of the materials it is impossible to determine the dip of the strata by tracing individual beds. From the position of the formation, however, between the gently inclined beds of the underlying Patuxent formation and the equally gently inclined marine beds of the Peedee formation above, it may be inferred that the dip is slight, probably not exceeding 20 feet to the mile and possibly much less.

Owing to the lack of data regarding the exact dip of the beds, it is impossible to estimate with any degree of accuracy the thickness of the formation. The width of the belt of outcrop in the Cape Fear River region is at least 30 miles. If the dip amounts to as much as 20 feet to the mile the thickness called for would be 600 feet. This estimate may be too large.

To the northward the formation becomes thinner rapidly, the thickness on the Neuse being perhaps less than one-half that on the Cape Fear; and on Contentnea Creek and Tar River still less. The fossil remains contained in the formation are for the most part those of plants. As above stated, lignite is common, being present as particles and pieces of all sizes from comminuted fragments up to large limbs or trunks, and fossil resin or amber is in many places associated with it. Leaf remains are common, having been collected up to the present time from over 20 localities. The great bulk of the material belongs to the more resistant types of plants, especially those capable of resisting

maceration, such as the conifers. However, in places, less resistant dicotyledons have been preserved, as is shown by their occurrence in a good condition of preservation on Cape Fear River at Court House Landing. The remains of marine invertebrates are common in the upper or transitional portion of the formation, and, in the same beds, bones, coprolites, and sharks' teeth have been observed at a few places.

(For the distribution and range of the invertebrate species of the Black Creek formation, see the table opposite page 147.)

Detailed Sections.—The most complete series of exposures of the Black Creek formation are those afforded by the Cape Fear River bluffs from a point about 101 miles above Wilmington in southern Cumberland County to Jessups Landing, 56 miles above Wilmington, or possibly as far as Donohue Creek Landing, 50⅓ miles above Wilmington, Bladen County. (See sketch map of Cape Fear River, Plate I, opposite p. 88.) In addition to the immediate river-bluff localities, there are a number of occurrences in Cumberland County which should be included in this series. The escarpment running north and south through Fayetteville just to the west of the Atlantic Coast Line Railroad depot furnishes a few poor exposures of Black Creek strata. The estimated thickness at this place is 30 feet. They consist of stratified or, in places, laminated sands and clays. In position they rest unconformably upon the strata of the Patuxent formation and are overlain by Pleistocene gravels and sands. The same beds are well exposed in cuts of the Atlantic Coast Line Railroad 1¼ to 2¼ miles southwest of the depot at Fayetteville. The materials at the latter place consist of irregularly bedded, white to yellow sand and light drab to black clay, with numerous thin sheets and thicker layers of ferruginous sandstone. There is one lens of black, sticky, lignitic clay several feet in thickness. They rest upon typical sands of the Patuxent formation, the exact contact, however, being somewhat obscured by talus material.

The feather edge of the formation has been observed at several places near Hope Mills in Cumberland County. Two of these occurrences have been described elsewhere. (See diagram and description of section 1 mile northeast of Hope Mills, p. 110, and description of section 1 mile south of Hope Mills, p. 111.)

A fossil plant locality in the Black Creek formation occurs on the left bank of Little Rockfish Creek about 100 yards above the Hope Mills-Fayetteville road bridge. The section is as follows:

SECTION ON LITTLE ROCKFISH CREEK, 100 YARDS ABOVE THE HOPE MILLS-FAYETTEVILLE ROAD BRIDGE, LEFT BANK.

	Feet.
Pleistocene:	
Coarse white sand, becoming gravelly at base and containing iron crusts	3
(Unconformity.)	
Cretaceous:	
Black Creek formation:	
Yellow, ferruginous, stratified sand, with some thin layers, grading into dark, slightly chocolate tinted, laminated clay and sand layers, the latter containing leaf remains, lignite, amber, and pyrites	8
(Unconformity.)	
Patuxent formation:	
Typical light gray, arkosic, banded sand and clay layers	25

From the Black Creek formation in the above described section the following fossil plants were collected:

Araucaria bladenensis Berry.
Ficus daphnogenoides (Heer) Berry.
Myrsine borealis Heer.
Podozamites Knowltoni Berry.
Sequoia Reichenbachi (Gein) Heer.
Tumion carolinianum Berry.
Teredo-bored logs.

An account of the first appearance of the formation observed in descending Cape Fear River between mileposts 101 and 98, where its feather edge occurs resting unconformably upon the Patuxent formation, has already been given. (See detailed sections and illustration, p. 98, and Figs. 1 and 2.)

The materials in these exposures consist of dark laminated sands and clays which contain a large amount of lignite in the form of large logs, smaller pieces and comminuted particles, and also in some of the exposures of an abundance of large irregular concretions of iron sulphide, probably in the form of marcasite. The lignite is in part distributed irregularly throughout the deposits, but in part the comminuted particles and small pieces are collected together in the form of seams. The sand partings contain a considerable percentage of mica. Descending the river, poor exposures of laminated materials were seen at Willis Creek Landing, milepost 96, and at T. M. Sykes' Landing, milepost 95.

Prospect Hall Bluff, just above milepost 93, presents a fine section of laminated sands and clays of this formation. The bluff is some 75 or 80 feet in height, it being one of the highest on the river. The

A.—Exposure of the Black Creek formation overlain by Pleistocene sands, Cape Fear River, Prospect Hall Bluff, 20 miles above Elizabethtown, N. C.

B.—Exposure of the Black Creek formation overlain by Miocene shell marl, Cape Fear River, Walkers Bluff, 13 miles below Elizabethtown, N. C.

upper 8 or 10 feet consists of loose white sand, except where locally indurated at base to an ironstone rock, of Pleistocene age. The section, Fig. 11, is a hasty sketch of that portion of the bluff which is best exposed for study.

Several good-sized silicified logs were observed lying loose on the lower slopes of the bluff. As none of these were seen in place, it could not be determined whether they came from the Pleistocene above or the laminated beds beneath. The highest one observed rested upon layer No. 3 at about 20 or 25 feet above the base.

S. N.

About 400 feet

FIG. 11.—Sketch showing the irregularly bedded character of the Black Creek formation; Cape Fear River, Prospect Hall Bluff, N. C.

EXPLANATION OF SECTION.

Pleistocene (Sunderland formation)

1. Loose white sand, except where locally indurated at base to form an ironstone rock.

Cretaceous (Black Creek formation):

2. Dark drab to black, laminated clay with partings and some lenses of sand. Contains some lignite and comminuted vegetable remains.
3. Rather loose, cross-bedded sand, with some laminæ of drab clay. Contains some lignite.
4. Dark drab, laminated clay and loose, light-colored sand.
5. Loose, buff, cross-bedded sand, with a few laminæ of clay.
6. Coarse, cross-bedded sandstone, cemented with iron.
7. Dark drab to black, laminated clay, containing much lignite, in places teredo-bored, concretions of iron sulphide, and much mica. Some of the lignite layers are essentially peat, and in these peaty layers the mica is especially abundant.

Phragmites Pratti Berry and *Salix flexuosa* Newberry were collected at this locality.

Laminated sands and clays, varying in character, but as a rule containing considerable lignite, iron sulphide concretions, and mica, are exposed at many points for the next 16 miles below Prospect Hall, for the most part in low, rather poor bluffs. At the mouth of Harrisons Creek, 83 miles above Wilmington, left bank, a 12- or 15-foot exposure of laminated materials yielded the characteristic Black Creek species *Araucaria bladenensis* Berry and *Phragmites Pratti* Berry.

The next high bluff is at Court House Landing, 77 miles above Wilmington, where the following section was made:

SECTION AT COURT HOUSE LANDING, MILEPOST 77.

	Feet.
Pleistocene (Sunderland formation?):	
Sandy loam, grading down into a loose, white sand	6
Yellowish to drab, sandy clay, grading down into next layer	3
Light, yellowish to reddish, coarse sand, with a few laminæ of drab clay	1.5
Drab clay, mottled with yellow	1
Coarse sand, mottled with yellow	2
(Unconformity.)	
Cretaceous (Black Creek formation):	
Dark bluish to black, thinly laminated clay, with fine micaceous sand partings in which occur comminuted vegetable particles	4.5
Coarse, loose sand, mottled with yellow, with a few laminæ of drab clay	1
Dark bluish to black, thinly laminated clay, with fine micaceous sand partings containing finely comminuted vegetable particles, stained yellow in places with sulphur	24
Light, somewhat indurated, sulphur-stained sand	1
(The 10 or 15 feet of materials included in the preceding layer and the base of the 24-foot layer above are very variable along the exposure. For some distance along one portion of the section the materials consist of pale yellow, very coarse, cross-bedded sand, the color being due to sulphur. Near the base of this sand there is at one place a lens of brownish clay and thin layers of iron-stained sand, some 20 feet long and 2½ feet in maximum thickness. The clay contains abundant remains of fossil plants.)	
Gray, yellow, and red cross-bedded sand, for the most part cemented with iron to a sandstone rock, containing lignite in places	3-5
Dark to black, laminated clay, with fine micaceous sand partings, more sandy in upper 2 feet and becoming interstratified with thicker sand layers in lower 4 or 5 feet. Contains some lignite with sulphur in places	26-28
Stratified and in places highly cross-bedded, grayish to reddish sand, with thin laminæ of dark clay, containing lignite in large and small pieces and finely comminuted particles	9

The following is a list of the plants collected and identified from the fossiliferous clay lens described above:

Andromeda grandifolia Berry.
Andromeda Parlatorii Heer.
Araucaria Clarki Berry.
Celastrophyllum crenatum Heer.
Celastrophyllum undulatum Newberry.
Cinnamomum Heerii Lesquereux (?).
Cornophyllum sp.
Diospyros primaeva Heer.
Eucalyptus attenuata Newberry.
Eucalyptus Geinitzi (Heer) Heer (common).
Ficus, fruits.

Ficus crassipes Heer (?).
Ficus ovatifolia Berry.
Ficus daphnogenoides (Heer) Berry.
Ficus inaequalis Lesq.
Ficus Stephensoni Berry.
Fern, undeterminable.
Hedera primordialis Sap.
Juglans arctica Heer.
Laurophyllum elegans Hollick.
Leguminosites robiniafolia Berry.
Liriodendron dubium Berry.
Liriodendron sp.
Magnolia Capellinii Heer.
Magnolia Newberryi Berry.
Menispermites sp. nov.
Myrica elegans Berry (the most common species).
Myrsine borealis Heer.
Myrsine elongata Newberry.
Phaseolites formus Lesq.
Phragmites Pratti Berry.
Pterospermites carolinensis Berry.
Pterospermites crednerafolia Berry.
Quercus Pratti Berry.
Quercus sp. nov.
Salix Newberryana Hollick.
Sassafras acutilobum Lesq.
Sequoia heterophylla Velen.
Zonarites sp.

Elizabethtown is 73¼ miles above Wilmington. In the roadway leading from the landing up to the village and at an elevation of perhaps 40 feet above the river, the following forms were obtained:

Ficus, fruits.
Myrica elegans Berry.
Moriconia americana Berry.
Salix flexuosa Newberry.

Below Elizabethtown there are a number of good sections, although a marked difference in the character of the materials begins to appear in some of the exposures. One-half mile below milepost 73 there is exposed along the left bank about 6 or 8 feet of dark green, micaceous sand, stratified for the first few feet at base and massive and compact above, containing scattered particles of lignite and a small percentage of glauconite. It has all the essential characters of a marine deposit. In the next 3 or 4 miles poor exposures of similar materials occur at several points.

At Sand Bluff Landing, a little below milepost 70, left bank, however, the materials consist of laminated, lignitic sands and clays similar to those above Elizabethtown, rising about 25 feet above the water's edge. (See Plate V, A.) They are overlain by 20 feet or more of loose, light-colored Pleistocene sand, with the usual gravel band at base containing crystalline bowlders and some silicified wood.

At 69 miles above Wilmington, left bank, there is a 5-foot exposure, consisting of dark, micaceous sands and clays, stratified and cross-bedded, very lignitic and containing occasional pieces of bones and turtle plates. Towards the lower end of the exposure a compact bed of dark glauconitic sand, several feet in thickness, overlaps the preceding, dipping downstream and disappearing in a short distance beneath the water's edge.

The next exposure of importance is at Phoebus Landing below milepost 68, right bank. The materials here consist of laminated, lignitic, and pyritiferous sands and clays of the usual character, rising 4 or 5 feet above the water's edge. For a distance of 400 or 500 feet the overlying Pleistocene, consisting of clay loam, sand, and gravel, has been removed by erosion back from the water's edge some 50 or 60 feet, leaving a bench of dark clays of the Black Creek formation, which slopes gently toward the river. Imbedded in the clay and also lying loose upon the surface of the Black Creek beds occur numerous broken pieces of large dinosaur bones, coprolites, crocodilian teeth, turtle and gavial plates, and sharks' teeth. The bones are badly broken and are for the most part in a poor state of preservation. Imbedded in the clay are a number of logs of lignite and silicified wood. Among the vertebrate remains from this locality which are now in the U. S. National Museum, the following forms have been identified by C. W. Gilmore:

DINOSAURIA:
- *Hypsibema crassicauda* Cope.
- *Trachodon tripos?* Cope.
- Carnivorous dinosaur (*Zatomis?*).

CROCODYLIDÆ:
- *Thecachampsa rugosa* Emmons.
- *Polydectes biturgidus* Cope.

TESTUDINATA:
- *Taphrosphys dares* Hay.
- *Amyda* sp.

At Big Sugar Loaf Landing, milepost 66, left bank, a fine section of Black Creek materials about one-fourth mile in length is exposed. The upper 20 feet of the section consists of very loose, white to buff, coarse and fine sand, with a gravel band at base, of Pleistocene age. The Black Creek materials underlying the loose sands vary widely in character along the bluff. They consist for the most part of dark laminated sands and clays. (See Plate V, B.) In places the clay predominates from top to bottom, while a short distance away at the same level occur great lenses of yellowish or buff sands, with very little clay. A large amount of lignite, in the form of large and small pieces of limbs, etc., in some instances teredo-bored, and comminuted particles, occurs in both the sands and clays. Some of the thin laminæ are made up almost entirely of comminuted vegetable particles. Pieces of lignite resembling charred wood are not uncommon. Both sands and clays are in places coated with yellow sulphur stain. A few

A.—Exposure of strata typical of the Black Creek formation overlain by white sands of Pleistocene age, Cape Fear River, Sand Bluff Landing, 3½ miles below Elizabethtown, N. C.

B.—Near view of laminated sands and clays typical of the Black Creek formation, Cape Fear River, Big Sugar Loaf Landing, 7½ miles below Elizabethtown, N. C.

poorly preserved fossil leaves were obtained here, the following being determinable: *Ficus daphnogenoides* (Heer) Berry, *Sequoia heterophylla* Velen.

This section is essentially the same, although offering a better exposure, as that at Sand Bluff Landing, above described. The Cretaceous portion of the cliff is nearly vertical and is even undermined in places. Springs come out all along the upper surface of the Cretaceous beds, making little waterfalls along the bluff.

Materials similar to the preceding were observed at Little Sugar Loaf Landing, milepost 65; Tom Smith's Landing above milepost 63, where a few dinosaur bones were observed; at Atkinson Landing, milepost 62, where one turtle plate was obtained, and at McCays Landing, milepost 61.

Walkers Bluff, milepost 60, presents a fine section of Black Creek materials, which is described in detail below. (See Plate IV, B, opposite p. 117.)

SECTION AT WALKERS BLUFF, MILEPOST 60, RIGHT BANK.

	Feet.
Pleistocene:	
Sunderland formation (?):	
Sandy loam	2
Mottled, reddish, and yellowish, arenaceous clay	1.5
(Unconformity.)	
Pliocene:	
Sand, clay, and shell marl	25
Cretaceous:	
Black Creek formation (?):	
Indurated layer of calcareous, fossiliferous sand rock. This is seen at the lower end of the bluff immediately below the Pliocene marl. Farther upstream it appears to be represented at the same level by loose, unconsolidated sand. Still farther upstream, where the slope is covered with vegetation, the river bank at low water is seen to be strewn with bowlders of this fossiliferous rock which have fallen down from above. The fossils are mostly in the form of casts and are difficultly determinable	1
Black Creek formation:	
Loose, gray, cross-bedded sand, interstratified with fine layers of drab clay	2
Orange to yellow, cross-bedded sand, with a few thin laminæ of drab clay	5
Thinly laminated drab clay, and orange, red, and drab cross-bedded sands, the sands predominating in the lower 5 feet	7
Thinly laminated, dark-blue clay, and dark drab to greenish-gray sand, very compact. The upper surface is nearly level, and the beds present an appearance strikingly different from all the	

	Feet.
materials above. The latter, however, are probably conformable upon the former. Lignite is present in greater or lesser amount throughout the mass, the surface is stained with sulphur in places, and a few gypsum crystals were observed.............	24
Indurated layer of sand containing rounded pellets of drab clay..	1
Light gray to yellow, compact, homogeneous sand, in places slightly indurated	3
Thinly laminated, dark-blue to black clay, with thin layers and larger lenses of gray sand, in places colored yellow with sulphur, the whole containing more or less lignite................	7

The indurated fossiliferous layer at the top of the Cretaceous portion of the section is questionably referred to the Black Creek formation, the forms present apparently indicating a position very close to the dividing line between the Black Creek and overlying Peedee formations. From this layer the following were identified:

U. S. G. S. LOCALITY Nos. 3354, 4145, 5338.

Serpula cretacea (Conrad).
Cucullaea antrosa Morton.
Arca sp.
Trigonoarca?
Ostrea sp.
Exogyra sp.
Trigonia sp.
Anomia lintea Conrad?
Pholadomya occidentalis Morton?
Veniella lineata Shumard?
Crassatellites sp.
Cardium spillmani Conrad.
Cardium longstretti Weller.
Cardium sp.
Aphrodina sp.
Corbula carolinensis Conrad.
Tellina sp.
Gastrochaena americana Gabb.
Lunatia obliquata M. & H.
Turritella trilira Conrad.
Anchura sp.
Pugnellus sp.
Undetermined pelecypods and gastropods.
Lamna texana Roemer.

Three miles below Walkers Bluff, at milepost 57, right bank, a marine bed with a few shells in close association with overlying laminated materials was observed from the deck of a passing steamboat.

At Jessups Landing, milepost 56, the following section occurs:

SECTION AT JESSUPS LANDING, LEFT BANK.

	Feet.
Pleistocene:	
Light colored, loose, coarse, cross-bedded sand, with cobbles and bowlders of crystalline rock at base..........................	16
(Unconformity.)	
Cretaceous (Black Creek formation):	
Laminated, dark-blue clay, and light gray, cross-bedded, glauconitic, micaceous sand, the whole mass quite lignitic, the lignite occurring as pieces of limbs, smaller fragments and comminuted particles, the latter aggregated in the form of seams in places. Some fragments resembling charred wood were observed. Some of the larger pieces of lignite are teredo-bored. Iron sulphide concretions are present in association with the lignite..........	12

In the autumn of 1905 this section was observed from the deck of a passing river boat. The water was then very low and there was revealed beneath the laminated materials a bed of Cretaceous shell marl in a matrix of compact marine sand or clay, several feet in thickness, which was not exposed when the above section was made. This is the last exposure of undoubted Black Creek materials observed in descending the river.

Just below Whitehall Landing, 53½ miles above Wilmington, right bank, about 8 or 10 feet of dark greenish clay is exposed above the water's edge. This is questionably regarded as belonging to the Black Creek formation.

At Deep Water Point, 51½ miles above Wilmington, left bank, there is exposed at extreme low water a layer of greenish-gray, calcareous and fossiliferous rock about 1 foot in thickness, of marine origin. It is underlain by a dark, unconsolidated shell marl containing many sharks' teeth and fragile Cretaceous fossils, about 1 foot being exposed above the water. These materials are questionably referred to the Black Creek formation. The rock forms a shelf along the cove side of the bend, and passes back under a covering of Pleistocene terrace materials.

Ten feet of dark-blue laminated clay forming the base of the bluff at Donohue Creek, 50⅓ miles above Wilmington, should perhaps be regarded as the top of the Black Creek formation, their lithologic character favoring this view. It is reasonably certain that the overlying strata in this section should be referred to the Peedee ("Burches Ferry") formation, the reference being based upon the presence of the fossils *Ostrea subspatulata* Forbes and *Exogyra costata* Say. (See section on page 147.)

In Sampson County a few poor exposures of weathered laminated sands and clays have been observed on one of the headwater tributaries of Black River between Roseboro and Clinton, which are believed to belong to the Black Creek formation. No work was done in the Black River Valley between these occurrences and Clear Run. One exposure of dark laminated beds was examined about 4 miles west of Tomahawk on South River, which forms the western boundary of Sampson County. On Black River outcrops of the formation have been studied from Clear Run in Sampson County to Horrell Landing in Bladen County. Throughout this distance as observed in the river bluffs the formation is everywhere overlain by Pleistocene terrace materials.

The Black River occurrences are described in detail on the following pages. (See sketch map of Black River, Fig. 12, p. 124.)

Below the wagon bridge at Clear Run there appears at low water about 12 feet of dark to black, laminated clay, with partings of fine micaceous sand and seams of lignite, mostly in a comminuted condition. Occasional larger pieces of lignite and small concretions of iron sulphide are present, scattered somewhat irregularly throughout the materials. The only determinable fossil plant obtained here was the characteristic Black Creek ("Bladen") form, *Araucaria bladenensis* Berry.

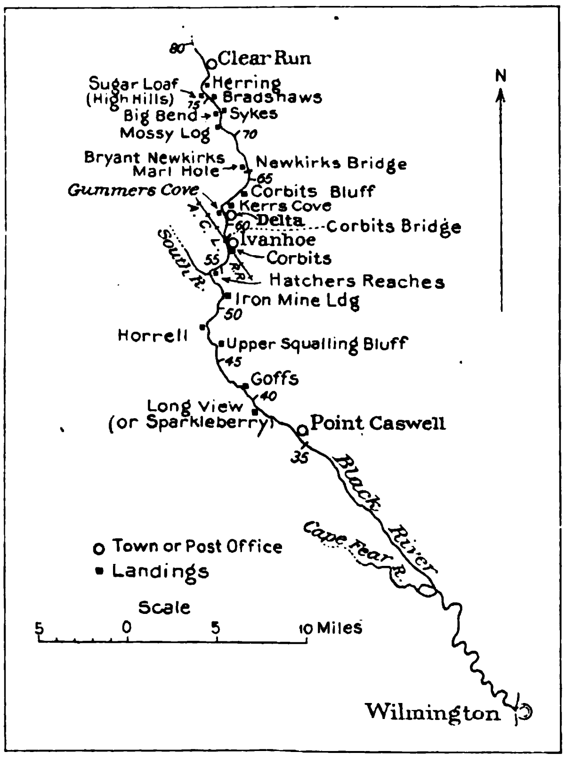


FIG. 12.— Sketch map of part of Black River, N. C.

At Sugar Loaf Bluff, 2¾ miles below Clear Run, there is a 25-foot exposure of Black Creek materials, consisting of dark, thinly laminated lignitic sand and clay.

At Bradshaws Landing, about 3 miles below Clear Run, the following section was made:

SECTION AT BRADSHAWS LANDING, 74¾ MILES ABOVE WILMINGTON, LEFT BANK.

Pleistocene:	FEET.
Yellow sandy loam, grading down into yellow sand, with a thin bed of gravel at base	7
(Unconformity.)	

Cretaceous (Black Creek formation):	FEET.
Dark, carbonaceous clay interlaminated with greenish-gray glauconitic sand, containing amber, lignite, and comminuted vegetable particles. Contains an occasional leaf of *Araucaria bladenensis* Berry and the seed of *Cephalotaxospermum carolineanum* Berry. A few bone fragments, probably turtle plates, and one coprolite were observed	2.5

At Sykes Landing, 74 miles above Wilmington, left bank, a section similar to the preceding is exposed, from which the following fossil plants were collected:

Araucaria bladenensis Berry.
Chondrophyllum Nordenskioldi Heer.
Cunninghamites elegans (Corda) Endl.
Cephalotaxospermum carolineanum Berry.

Near the site of an old mill one-fourth mile northeast of Sykes Landing, on land owned by C. S. Bradshaw, a few shell prints were obtained from fragments of sandstone which according to the owner were dug from a rock layer closely underlying the surface in the immediate vicinity of the mill. This rock is probably a lens in the Black Creek formation. The forms include *Glycymeris (?)*, *Cardium* sp., *Tellinimera (?)*, etc. (U. S. G. S. Loc. No. 5355.)

The next interesting exposure observed was at Big Bend, where the following strata appear:

SECTION AT BIG BEND, 73¾ MILES ABOVE WILMINGTON, RIGHT BANK.

Pleistocene:	FEET.
Loam, clay, and sand, with a pebble band along base	7
(Unconformity.)	
Cretaceous (Black Creek formation):	
Dark greenish-gray, tough, carbonaceous clay, in places laminated with thin sand partings. Contains amber, pyrites, lignite, and fossil leaves	6

The following fossil plants were collected from this outcrop:

Andromeda novae-caesareae Hollick.
Araucaria bladenensis Berry.
Araucaria Jeffreyi Berry.
Chondrophyllum Nordenskioldi Heer.
Cycadinocarpus circularis Newberry.
Salix flexuosa Newberry.
Salix Lesquereuxi Berry.
Cephalotaxospermum carolineanum Berry.

For the next two miles there are numerous low exposures of laminated Black Creek materials.

At the upper end of a low terrace bluff at Mossy Log Landing, 71½ miles above Wilmington, the following section occurs:

SECTION AT UPPER END OF BLUFF AT MOSSY LOG LANDING, 71½ MILES ABOVE WILMINGTON, RIGHT BANK.

	Feet.
Pleistocene:	
Loose gray sand	3
(Unconformity.)	
Cretaceous (Black Creek formation):	
Dark greenish-gray, slightly arkosic, compact, argillaceous and in places ferruginous sand, containing soft shell casts	4
Laminated, dark to black clay and gray or ferruginous sand, in which were observed a few poorly preserved specimens of *Araucaria bladenensis*	7

The fossils listed below were obtained from the greensand layer.

U. S. G. S. LOCALITY No. 5357.

Serpula sp.
Nucula n. sp. (aff. *N. percrassa* Conrad).
Arca sp.
Trigonoarca sp.
Trigonia (probably new species).
Pecten n. sp.
Pholadomya sp. (specimen destroyed).
Cymella bella Conrad.
Crassatellites carolinensis Conrad.
Cardium longstreeti Weller.
Cardium sp.
Isocardia cliffwoodensis Weller.
Linearia metastriata Conrad.
Leptosolen biplicata Conrad.
Corbula carolinensis Conrad.
Undetermined pelecypods.

Between Mossy Log Landing and Gummers Cove 60⅝ miles above Wilmington there are a number of low exposures of marine beds consisting of dark green or greenish-gray, fossiliferous sand with an occasional indurated, calcareous layer likewise fossiliferous. Collections of fossils were made wherever possible, and on the following pages are given lists of the forms identified.

U. S. G. S. LOCALITY No. 5356—BLACK RIVER, N. C., 69 MILES ABOVE WILMINGTON, N. C., RIGHT BANK.

Cymella bella Conrad.
Corbula carolinensis Conrad.
Undetermined pelecypods.

U. S. G. S. LOCALITY No. 5358—BLACK RIVER, N. C., BRYANT NEWKIRK'S MARL HOLE, 66 MILES ABOVE WILMINGTON, N. C.

Serpula cretacea (Conrad).
Nucula n. sp. (aff. *N. percrassa* Conrad).
Arca sp.
Cucullaea antrosa Morton?
Trigonoarca triquetra Conrad.
Trigonoarca n. sp.
Glycymeris subaustralis (d'Orbigny).
Pinna sp.
Ostrea cretacea Morton.
Trigonia sp.
Pecten n. sp.
Crassatellites carolinensis Conrad.
Cardium longstreeti Weller.
Cardium eufaulense Conrad.
Cardium spillmani Conrad.
Cardium sp.
Cyclothyris sp.

Linearia metastriata Conrad.
Corbula carolinensis Conrad.
Gastrochaena? (same as at Whiteley Creek Landing).
Undetermined pelecypods.
Lunatia sp.
Turritella sp.
Undetermined gastropods.
Lamna texana Roemer.
Otodus appendiculatus Agassiz.
Corax falcatus Agassiz.
Turtle plate.

U. S. G. S. LOCALITY No. 5359—BLACK RIVER, N. C., 64 MILES ABOVE WILMINGTON, N. C.

Hamulus major Gabb.
Nucula n. sp. (aff. *N. percrassa* Conrad).
Arca sp.
Trigonoarca triquetra Conrad.
Trigonoarca (probably new species).
Glycymeris subaustralis (d'Orbigny).
Ostrea cretacea Morton.
Trigonia eufalensis Gabb?
Pecten n. sp. *argillensis* Conrad.
Anomia lintea Conrad.
Pholadomya occidentalis Morton?
Cymella bella Conrad.
Etea carolinensis Conrad.
Veniella conradi (Morton).
Crassatellites carolinensis Conrad?
Cardium longstreeti Weller?
Cardium eufaulense Conrad.
Cardium sp.
Undetermined pelecypods.
Gyrodes crenata Conrad.
Turritella vertebroides Morton?
Undetermined gastropods.
Lamna texana Roemer.

U. S. G. S. LOCALITY No. 5360—BLACK RIVER, N. C., CORBITT'S BLUFF, 63½ MILES ABOVE WILMINGTON, N. C.

Hamulus major Gabb.
Nucula n. sp. (aff. *N. percrassa* Conrad).
Trigonoarca triquetra Conrad.
Glycymeris subaustralis (d'Orbigny).
Ostrea cretacea Morton.
Pecten n. sp.
Anomia argentaria Morton.
Anomia lintea Conrad.
Cymella bella Conrad.
Crassatellites carolinensis Conrad? (same as at Whiteley Creek Landing).
Crassatellites (probably new species; same as at Whiteley Creek Landing).
Cardium sp.
Corbula carolinensis Conrad.
Undetermined pelecypods.
Hamulus major Gabb.
Turritella vertebroides Morton?
Otodus appendiculatus Agassiz.

U. S. G. S. LOCALITY No. 5361—BLACK RIVER, N. C., 62½ MILES ABOVE WILMINGTON, N. C.

Hamulus major Gabb?
Trigonoarca triquetra (Conrad).
Trigonoarca n. sp. (same as at Kerr's Cove).
Glycymeris sp.
Ostrea cretacea Morton.
Pecten n. sp.
Anomia lintea Conrad.
Cymella bella Conrad.
Veniella conradi (Morton).
Crassatellites carolinensis Conrad?
Crassatellites (probably new species).
Cardium sp.
Corbula carolinensis Conrad.
Undetermined pelecypods.
Turritella vertebroides Morton?

U. S. G. S. LOCALITY Nos. 4153 AND 5382—BLACK RIVER, N. C., KERR'S COVE, 62½ MILES ABOVE WILMINGTON, N. C.

Bryozoa.
Serpula cretacea (Conrad).
Hamulus major Gabb.
Nucula n. sp. (aff. *N. percrassa* Conrad).
Leda n. sp. (same as at Blue Banks Landing).
Nemodon eufalensis Conrad?
Trigonoarca triquetra Conrad.
Trigonoarca n. sp. (same as at Black River, 62½ miles above Wilmington, N. C.).
Arca sp.
Ostrea cretacea Morton (very abundant).
Ostrea tecticosta Gabb.
Ostrea plumosa Morton.
Ostrea n. sp. (with fine striations).
Trigonia n. sp.
Pecten n. sp.
Anomia tellinoides Conrad.
Anomia n. sp.
Cymella bella Conrad.
Veniella conradi (Morton).
Crassatellites carolinensis Conrad.
Crassatellites pteropsis Conrad.
Cardium sp. (large).
Isocardia sp.
Cyclothyris carolinensis Conrad.
Aphrodina?
Linearia metastriata Conrad.
Legumen planulatum (Conrad).
Solyma?
Corbula carolinensis Conrad.
Undetermined pelecypods.
Turritella vertebroides Morton?
Gyrodes?
Otodus appendiculatus Agassiz.
Portheus sp. indet. (same as at Snow Hill, N. C. Identified by J. W. Gidley).

U. S. G. S. LOCALITY No. 3355—BLACK RIVER, N. C., GUMMERS COVE, ½ MILE ABOVE DELTA, N. C., 60½ MILES ABOVE WILMINGTON, N. C.

Ostrea cretacea Morton (abundant).
Anomia argentaria Morton.

This horizon probably occupies a position very nearly the same as that at Kerrs Cove.

At the A. C. L. Railroad bridge, milepost 58, laminated plant-bearing beds again appear, as described in the following section:

SECTION AT A. C. L. R. R. BRIDGE, 58 MILES ABOVE WILMINGTON, RIGHT BANK.

	FEET.
Pleistocene:	
Sand with thin gravel band at base...........................	12
(Unconformity.)	
Cretaceous (Black Creek formation):	
Dark to black, laminated, carbonaceous clay, containing fossil leaves, lignite seams and layers, larger lignite fragments, iron sulphide concretions, and amber, alternating with sand layers from thin seams up to layers 1 foot in thickness. The sand is micaceous and more or less glauconitic......................	27

A list of the determinable plant remains, from the above-described Black Creek formation is given below:

Andromeda novae-caesareae Hollick.
Araucaria bladenensis Berry.
Araucaria Jeffreyi Berry.
Malapoenna horrellensis Berry.
Cephalotaxospermum carolineanum Berry.

The next exposure, $\frac{1}{4}$ mile below the preceding, at Corbits (Old Union) Bridge, presents 5 feet of laminated materials essentially like the preceding and furnishes a closely similar assemblage of forms. The list follows:

Araucaria bladenensis Berry.
Chondrophyllum Nordenskioldi Heer.
Cunninghamites elegans (Corda) Endl.
Kalmia brittoniana Hollick?
Malapoenna horrellensis Berry.
Cephalotaxospermum carolineanum Berry.

Near Ivanhoe, $56\frac{7}{8}$ miles above Wilmington, left bank, the Black Creek species *Chondrophyllum Nordenskioldi* Heer was obtained in close association with the following scarcely determinable pelecypod casts, etc.: *Leda* sp., *Pecten* sp., *Crassatellites* sp., *Cardium* sp., undetermined pelecypods, crab claws. (U. S. G. S. Locality No. 5363.) The material containing these forms is similar to that at the two preceding localities.

One-eighth mile below the preceding, marine beds again make their appearance, a section of which is given below:

SECTION AT 56¾ MILES ABOVE WILMINGTON, LEFT BANK.

	Feet.
Pleistocene:	
Yellow sand	10
(*Unconformity.*)	
Cretaceous (Black Creek formation):	
Dark-green, finely micaceous, sandy, glauconite clay with scattered bits of lignite, vegetable particles and amber, and containing soft casts of shells	4
Yellow, sulphur-stained sand	2
Concealed to water's edge	5

A list of the determinable casts from the greensand layers is given below:

U. S. G. S. LOCALITY No. 5364.

Bryozoa.
Nucula n. sp. (aff. *N. percrassa* Conrad).
Leda cliffwoodensis Weller?
Arca?
Trigonoarca cliffwoodensis Weller.
Anomia lintea Conrad?
Cymella bella Conrad.
Veniella conradi (Morton).
Crassatellites carolinensis Conrad?
Cardium longstreeti Weller?
Cardium eufaulense Conrad?
Undetermined pelecypods.
Turritella sp.
Ammonite (indeterminable fragments of cast).

At Hatchers Reaches, $54\frac{1}{2}$ miles above Wilmington, left bank, an indurated layer of gray, calcareous, fossiliferous limestone, barely exposed at extreme low water, yielded the following forms:

U. S. G. S. LOCALITY No. 5365.

Bryozoa.
Hamulus major Gabb.
Serpula cretacea (Conrad)?
Nucula n. sp. (aff. *N. percrassa* Conrad).
Trigonoarca triquetra Conrad.
Nemodon eufalensis Conrad?
Arca sp.
Ostrea sp.
Exogyra sp.
Anomia argentaria Morton.
Anomia lintea Conrad.
Modiola?
Crassatellites carolinensis Conrad.
Cardium longstreeti Weller.
Cardium eufaulense Conrad.
Cyprimeria depressa Conrad.
Isocardia cliffwoodensis Weller.
Linearia metastriata Conrad.
Undetermined pelecypods.
Turritella sp.
Lamna texana Roemer.
Otodus appendiculatus Agassiz.
Corax falcatus Agassiz.

At Iron Mine Landing the following section is presented:

SECTION AT IRON MINE LANDING, 51 MILES ABOVE WILMINGTON, LEFT BANK.

	Feet.
Pleistocene:	
Dark brown, rather coarse, ferruginous sand	8
(Unconformity.)	
Cretaceous (Black Creek formation):	
Dark greenish-gray, sandy, micaceous, compact clay, with a few soft casts	7
Indurated layer of gray, calcareous sandstone	1½
Layer of rotten shell marl with gray sand matrix	2½
Indurated, siliceous, shell marl layer	1

The list of forms obtained at the above locality is given below:

U. S. G. S. LOCALITY No. 5366.

Serpula cretacea (Conrad).
Trigonoarca triquetra Conrad?
Glycymeris subaustralis (d'Orbigny).
Ostrea subspatulata Forbes.
Ostrea plumosa Morton.
Ostrea n. sp. (fine striations).
Exogyra ponderosa var. *erraticostata* Stephenson.
Trigonia (probably new species).
Pecten n. sp.
Anomia n. sp.
Pholadomya n. sp.
Anatimya?
Etea carolinensis Conrad.
Veniella conradi (Morton).
Cardium eufaulense Conrad?
Cardium longstreeti Weller.
Cardium spillmani Conrad.
Cardium sp.
Aphrodina regia Conrad.
Aphrodina?
Cyclothyris alta Conrad.
Legumen planulatum (Conrad).
Leptosolen biplicata Conrad.
Schizodesma?
Undetermined pelecypods.
Lunatia sp.
Anchura sp.
Turritella trilira Conrad.

The last exposure of the Black Creek formation observed in descending Black River is at Horrell Landing, where the following section is exposed:

SECTION AT HORRELL LANDING, 48½ MILES ABOVE WILMINGTON, RIGHT BANK.

Pleistocene:	FEET.
Loamy sand, becoming coarse at base	5
(Unconformity.)	
Cretaceous (Black Creek formation):	
Laminated, dark, carbonaceous, lignitic clay and greenish-gray sand, well preserved leaf remains	1-1½
Dark greenish-gray, marine sand and clay	4

The following is a list of the plant remains collected from the fossiliferous portion of the above section:

Araucaria bladenensis Berry.
Chondrophyllum Nordenskioldi Heer.
Cunninghamites elegans (Corda) Endl.
Malapoenna horrellensis Berry.

In the southern part of Johnston County, at Bentonville, and on the side of the valley of Stone Creek where it is crossed by the Smithfield and Wilmington wagon road, there have been observed a few poor exposures of white to yellow sand with lenses and laminæ of drab, purple, and chocolate clay, which are believed to form a weathered phase of the Black Creek formation.

Exposures of the Black Creek formation occur in the bluffs of Neuse River from Blackmans Bluff, 117½ miles above New Bern, in Wayne County, to Whiteley Creek Landing, 60 miles above New Bern. From the first-named point to the A. C. L. Railroad bridge southwest of Goldsboro the formation rests unconformably upon the undulating surface of the Patuxent formation, which at the latter point passes finally below water level. It is overlain unconformably by Pleistocene terrace deposits and by several basin-like occurrences of Eocene strata. Below Whiteley Creek Landing the beds are believed to pass conformably beneath the overlying Peedee formation. (See sketch map of Neuse River, Fig. 4, p. 96.)

In descending the river from Smithfield the first high land observed approaching close to the river banks was at Blackmans Bluff. Here the Black Creek formation was first seen. The lower 20 feet of the section was exposed at the time, the water being 4 or 5 feet above normal.

SECTION AT BLACKMANS BLUFF, RIGHT BANK.

Pleistocene:	FEET.
Concealed by vegetation	30
Cretaceous (Black Creek formation):	
Drab to brownish drab, sandy, micaceous clay	12
Stratified, iron-stained sand, and drab to dark or brownish drab clay, containing leaf impressions, comminuted vegetable particles, small pieces of lignite, a few concretions of iron sulphide, occasional bits of amber and pieces of silicified wood. Near the base the sand lenses are in places indurated	8

About ½ mile farther downstream the same upland bluff is cut by the river and a section essentially the same as the preceding is revealed. The same species of plants were found at about the same level. It is probable that the Patuxent formation occurs a short distance below the water level here, and might be exposed at a low-water stage.

In the two preceding sections the following fossil plants were collected:

Acerates amboyense Berry.	*Eucalyptus nervosa* Newb.
Andromeda novae-caesareae Hollick.	*Kalmia brittoniana* Hollick?
Chondrophyllum Nordenskioldi Heer.	*Liriodendron cf. primaevum* Newb.
Dewalquea groenlandica Heer.	*Planera cretacea* Berry.

At a spring a few hundred yards back from the river and at a higher level than the materials revealed in the preceding sections a poor exposure of Eocene limestone occurs, which, although the contact was not seen, probably overlies and rests directly upon the Black Creek formation.

In a section at milepost 105, right bank, 10 feet of Black Creek materials appear resting unconformably upon the Patuxent formation and overlain by questionable Tertiary beds. A detailed account of this section is given on page 97. The materials here are irregularly bedded, consisting in part of dark drab, thinly laminated clay with some lignite, and in part of large lenses of yellowish stratified sand.

At about milepost 104, a few feet of laminated Black Creek materials were observed at the base of a low bluff on the right bank.

At 97½ miles above New Bern the following section was made:

SECTION AT 97½ MILES ABOVE NEW BERN.

	Feet.
Pleistocene:	
Yellow sandy loam, grading down into coarse yellow sand with a thin band of gravel at base containing quartz and crystalline pebbles	14
(Unconformity.)	
Cretaceous (Black Creek formation?):	
Gray, sandy, carbonaceous clay, in places near the base interstratified with rather coarse sand, and containing some good-sized logs of lignite, partly in the condition of brown lignite, and an abundance of iron pyrites in the form of irregular concretions........	9

A section essentially the same as the preceding occurs at 95½ miles above New Bern.

The unconformable relations of the Patuxent and Black Creek formations are well exhibited in an exposure at the county-road bridge 2 miles southwest of Goldsboro and 94¾ miles above New Bern. The

details of this section are given on p. 98. (See, also, Plate III, B, opposite p. 98.) The Black Creek materials here consist of dark to black laminated clay with partings and thin layers of fine, micaceous, slightly glauconitic sand, the whole more or less lignitic. Similar material appears in a section at the A. C. L. Railroad bridge ¾ mile below the preceding. (See section, p. 99.) Here, also, they rest upon the Patuxent formation. This is the last place at which the Patuxent formation appears above water level.

At milepost 93 a low-water stage reveals about 3 feet of laminated, lignitic sand and clay of the Black Creek formation. The thin sand partings contain grains of glauconite.

At milepost 92, ⅛ mile above Arringtons Bridge, 6 feet of Black Creek materials similar to the preceding is exposed along the left bank. They contain lignite, grains of amber, and pyrites. In a lens of dark clay about 4 feet above the base the following plant species were collected:

Araucaria bladenensis Berry.
Araucaria Jeffreyi Berry.
Podozamites sp.
Sequoia Reichenbachi (Gein) Heer.

Associated with the plant remains were a few indeterminable casts of pelecypod shells.

Between the preceding and a point 87⅝ miles above New Bern there are occasional exposures of characteristic Black Creek materials in most places rising only a few feet above low-water level. At several places the beds present a slightly more marine aspect than is exhibited by typical Black Creek materials, as shown by the occurrence of glauconite grains in the thin sand layers and partings. At the last-named point there is a 2-foot exposure of black clay with fine sand laminæ in which the writer collected a few leaf remains associated with poor casts of *Leda, Cardium*, etc. (U. S. G. S. Loc. No. 5350.) The plant species are as follows:

Araucaria bladenensis Berry.
Araucaria Jeffreyi Berry.
Ficus daphnogenoides (Heer) Berry.

A short distance below the preceding *Araucaria bladenensis* Berry and a large undetermined leaf were obtained.

Between the last-named locality and the Sarpony Hills, 83¼ miles above New Bern, there are several occurrences of Black Creek materials presenting no unusual characters.

At the latter point the river touches the base of a hill whose height exceeds 100 feet. From the water's edge to a height of at least 83 feet this bluff consists of Eocene limestone, which appears to fill a deep depression in the eroded Cretaceous surface.

At milepost 83, 4 feet of laminated, dark greenish-gray, glauconitic sand and clay appears at the base of a low Pleistocene terrace section. At Broadhurst Bridge, 82¼ miles above New Bern, a few feet of Eocene limestone is again seen at the water's edge. About 100 yards below Broadhurst Bridge, milepost 82, the following section was obtained:

SECTION AT MILEPOST 82, RIGHT BANK.

	Feet.
Pleistocene:	
Loam and sand with gravel band at base	8
(Unconformity.)	
Cretaceous (Black Creek formation):	
Dark greenish-gray, micaceous sand, in places coarse, and in places interlaminated with dark clay layers and elsewhere with lighter sand layers	8

Essentially the same kind of materials are exposed almost continuously along the right bank for the next two-thirds mile.

The first marine materials observed containing determinable fossils were at a point 79¼ miles above New Bern. The section is as follows:

SECTION 79¼ MILES ABOVE NEW BERN, RIGHT BANK.

	Feet.
Pleistocene:	
Loam and sand with a band of gravel at base	6
Cretaceous (Black Creek formation):	
Greenish-gray, marine sand containing pelecypod casts as follows: *Nemodon cufalensis* Conrad?, *Trigonia* sp., *Crassatellites carolinensis* Conrad, *Isocardia cliffwoodensis* Weller, *Cyprimeria depressa* Conrad, *Cyclothyris alta* Conrad?, *Leptosolen biplicata* Conrad. (U. S. G. S. Locality No. 5418)	6

Dark greenish-gray, glauconitic sand appears a short distance below milepost 77, left bank, beneath about 10 feet of Pleistocene materials. From this was obtained indeterminable pyrites casts of the genus *Perna* (U. S. G. S. Loc. No. 5351).

At a point locally known as "The Cliffs," 76½ miles above New Bern and just above Ivys Landing, the river again strikes against high land, and the following fine section is exposed:

SECTION AT "THE CLIFFS" ABOVE IVYS LANDING, 76½ MILES ABOVE NEW BERN.

	Feet.
Pleistocene:	
Sunderland formation (?):	
Light-yellow sand	12
Band of small pebbles with sand matrix	1.5
(Unconformity.)	

Cretaceous:

Black Creek formation:	FEET.
Light greenish-gray sand, mottled with yellow..................	5
Dark to black clay, chocolate-colored where weathered, with seams of fine sand and seams of peaty material in which occur small amber grains, the whole mottled with yellow..................	4
Chocolate-colored, sandy clay, mottled with sulphur and iron stain.	1.5
Pale greenish-yellow, fine-grained, cross-bedded sand, with a large percentage of brown, partially weathered, glauconite grains.....	4
Chocolate-colored, sandy clay, with laminæ of sand at base, mottled with sulphur and iron stain..................................	2.5
Pale greenish-yellow, glauconitic, cross-bedded sand, with some clay laminæ. The glauconite grains are weathered brown......	1.5
Chocolate-colored, glauconitic, coarse, sandy clay, becoming more sandy at base..	3
Chocolate-colored clay interlaminated with green and yellow glauconitic sand	2.5
Light argillaceous sand, mottled with chocolate tints.............	3.5
Dark, chocolate-colored, slightly indurated, argillaceous sand.....	4
Pale greenish yellow, and darker chocolate-colored sands, more or less argillaceous in different layers, mottled with iron and sulphur stain, and containing some indeterminable shell casts......	25
Yellow and purple, coarse, ferruginous, cross-bedded sand, for the most part indurated to sandstone.............................	11

Between this point and Seven Springs (milepost 75) there are two other bluffs presenting sections essentially like the preceding, though not so high. In the first of these (milepost 76) a layer of sand about 20 feet above the base contains soft casts of shells, among which were recognized the following genera: *Pinna, Cardium, Aphrodina, Mactra?, Pugnellus,* large fusiform gastropod, *Nautilus,* etc. (U. S. G. S. Loc. 4163).

At Seven Springs, milepost 75, a few feet of dark greenish-gray, glauconitic sand appears overlain by about 10 feet of Pleistocene sand. The greensand contains some small pieces of lignite.

About ½ mile west of Seven Springs a few rods below what is known as the "Ninth Spring" and back from the river about ¼ mile, there is a 3-foot exposure of dark green marine clay, one layer of which contains an abundance of soft clay casts. The elevation of this layer above the water level in the river, as nearly as could be determined by rough leveling, is 15 feet. The following is a list of the forms identified:

U. S. G. S. LOCALITY No. 5352.

Nemodon brevifrons Conrad.	*Pecten* n. sp.
Glycymeris congesta Conrad.	*Anatina?*
Glycymeris sp.	*Cymella bella* Conrad.
Trigonoarca triquetra Conrad.	*Veniella conradi* (Morton).

Etea carolinensis Conrad.
Cardium sp.
Isocardia cliffwoodensis Weller?
Aphrodina sp.
Cyclothyris?
Legumen planulatum (Conrad).
Leptosolen biplicata Conrad.
Schizodesma appressa Gabb.
Corbula carolinensis Conrad.
Turritella sp.
Gyrodes?
Anchura sp.

Augur Hole Landing, milepost 73, left bank, presents the following section:

SECTION AT AUGER HOLE LANDING, MILEPOST 73, LEFT BANK.

	Feet.
Pleistocene:	
Yellow loamy clay and sand, with a band of gravel at base.......	3-7
(Unconformity.)	
Cretaceous (Black Creek formation):	
Dark greenish-gray, more or less argillaceous sand, with an indurated layer 1 to 2 feet thick near base. Very fossiliferous, the fossils being in the form of shells and casts. The shells are for the most part fragile. Locally, just above the indurated layer, the shells are fragmentary, constituting a loose coquina material	6

The following is a list of the fossils collected at the above locality:

U. S. G. S. LOCALITY Nos. 4160 AND 5353.

Hamulus major Gabb.
Serpula sp. (straight tube).
Nucula n. sp. (aff. *N. percrassa* Conrad).
Cucullaea antrosa Morton?
Nemodon eufalensis Conrad.
Arca sp.
Glycymeris congesta (Conrad).
Breviarca sp.
Trigonoarca n. sp.
Gervillia ensiformis Conrad.
Ostrea cretacea Morton?
Ostrea tecticosta Gabb.
Gryphaea vesicularis Lamarck.
Exogyra ponderosa Roemer.
Pecten n. sp.
Plicatula sp.
Lima oxypleura (Conrad).
Lima reticulata Forbes.
Lima pelagica (Morton).
Anomia n. sp.
Cymella bella Conrad.
Veniella conradi (Morton).
Etea carolinensis Conrad.
Crassatellites carolinensis Conrad.
Lucina glebula Conrad.
Cardium longstreeti Weller.
Cardium eufaulense Conrad?
Cyprimeria depressa Conrad.
Cyprimeria densata (Conrad).
Aphrodina regia Conrad?
Tellina sp.
Legumen planulatum (Conrad).
Cymbophora lintea (Conrad).
Corbula carolinensis Conrad.
Corbula crassiplica Gabb.
Anchura (probably new species, same as at Snow Hill, N. C.).
Ataphrus kerri Gabb?
Undetermined pelecypods and gastropods.
Fish vertebra.
Lamna texana Roemer.
Otodus appendiculatus Agassiz.
Corax falcatus Agassiz.

Of the 35 or more determinable species, about 25 are identical with species occurring at Snow Hill, N. C., and it is probable that this bed is approximately synchronous with that horizon.

At milepost 72, 22 miles above Kinston, left bank, the following forms were obtained in a low exposure: *Leda* sp., *Nemodon?*, *Arca* sp., *Cymella bella* Conrad, *Lunatia?*, *Anchura?*, *Otodus appendiculatus* Agassiz. (U. S. G. S. Loc. No. 4138.) From this point to milepost 60 there are occasional low exposures of greensand or dark marine clay, the latter in places containing soft casts of shells, and both the sand and clay in places contain poorly preserved fossil shells.

At 62½ miles above New Bern (12½ miles above Kinston), left bank, the following forms were obtained: *Cymella bella* Conrad, *Crassatellites carolinensis* Conrad, and *Corbula* sp.? (U. S. G. S. Loc. No. 4135.)

At Whiteley Creek Landing, milepost 60, the river bank presents a section about ⅓ mile in length which is essentially the same in character throughout and which may be represented by the following general section:

SECTION AT WHITELEY CREEK LANDING, MILEPOST 60, RIGHT BANK.

	Feet.
Pleistocene:	
Yellow sandy clay loam, grading down into coarse sand with a thin band of gravel along base	6-10
(Unconformity.)	
Cretaceous (Black Creek formation):	
Dark greenish-gray, rather coarse, glauconitic sand, with several more or less discontinuous indurated layers between top and bottom. Very fossiliferous, the fossils being soft except in the indurated layers	8-10

The contained fauna, which is listed below, indicates that this horizon occupies a position very close to the dividing line between the Black Creek and Peedee formations. The absence, however, of such forms as *Ostrea larva* Lamarck, the typical form of *O. subspatulata* Forbes, and *Belemnitella americana* Morton, points to its being somewhat older than the typical Peedee formation, and it is therefore tentatively referred to the upper part of the Black Creek formation.

U. S. G. S. LOCALITY Nos. 4136 AND 5354—NEUSE RIVER, WHITELEY CREEK LANDING, N. C., 60 MILES ABOVE NEW BERN, N. C. (EXPOSURE EXTENDS ⅓ MILE ABOVE LANDING.)

Stephanophyllia sp. (near *S. bowerbankii* M. E. & H. Iden. by T. W. Vaughan.)
Serpula cretacea (Conrad).
Cucullaea antrosa Morton.
Nemodon brevifrons Conrad.
Arca rostellata Morton?
Glycymeris subaustralis (d'Orbigny).
Perna n. sp.
Ostrea subspatulata Forbes?
Ostrea plumosa Morton.
Ostrea n. sp. (same as at Blue Banks Landing, N. C.).
Ostrea n. sp.
Exogyra sp.
Trigonia n. sp. (probably same as at Snow Hill, N. C.).
Pecten n. sp.

Anomia linifera Conrad.
Anomia argentaria Morton.
Crenella n. sp.
Dreissensia sp.
Pholadomya?
Etea carolinensis Conrad.
Crassatellites carolinensis Conrad.
Crassatellites (probably new species).
Brachymeris alta Conrad.
Cardium eufaulense Conrad.
Cardium spillmani Conrad.
Cardium dumosum Conrad.
Cardium sp.
Isocardia n. sp.
Aphrodina tippana Conrad?
Aphrodina regia Conrad.
Aphrodina sp.
Linearia (Liothyris) carolinensis Conrad.
Tellina?
Gastrochaena? (same as at Bryant Newkirk's Landing, N. C.)
Undetermined pelecypods and gastropods.
Fish vertebra.
Lamna texana Roemer.
Otodus appendiculata Agassiz.

The width of the belt of outcrops of the Black Creek formation where it crosses Contentnea Creek Valley is nearly 10 miles, the exposures occurring from a point about 2 miles below Speights Bridge to the vicinity of the twenty-fifth milepost, or about 6 miles below Snow Hill. For the first few miles of the distance the formation rests with unconformable relations upon the Patuxent formation. The exposures are all low, not exceeding 12 or 14 feet above water level. Except where removed by Pleistocene terracing processes, the overlying beds are believed to be of Miocene age, although no good exposures showing these relations were observed. (See sketch map of Contentnea Creek, Fig. 4, p. 96.)

At the locality indicated about 2 miles below Speights Bridge, right bank, the Black Creek formation first makes its appearance, the materials consisting of typical, dark drab to black, laminated clays, with partings of fine micaceous sand, the whole more or less lignitic. There it rests unconformably upon the Patuxent formation, and for several hundred yards along the bank the undulating upper surface of the latter is observed to rise and fall 4 or 5 feet above and below water level. For the next few miles the only Cretaceous materials appearing in the river banks belong to the Patuxent formation, but at a point about three-fourths of a mile above Fools Bridge the Black Creek formation again appears.

SECTION ¾ MILE ABOVE FOOLS BRIDGE (CONTENTNEA P. O.), FALKLAND QUADRANGLE, RIGHT BANK, CONTENTNEA CREEK.

	Feet.
Pleistocene:	
Loamy clay	4
Reddish, iron-stained, coarse, cross-bedded sand, with a band of gravel at base..	2
(Unconformity.)	

Cretaceous (Black Creek formation): FEET.

Laminated, dark drab to black clay, with partings and lenses of fine sand, containing a large amount of lignite in form of logs, which are in places teredo-bored, smaller pieces and comminuted particles. Irregular iron sulphide concretions are also present. Near the base the sand lenses are in places indurated with iron oxide and in places the surface of the exposed materials is coated yellow with sulphur stain.................... 6

From here to a point about 4 miles below Fools Bridge (Contentnea P. O.) similar laminated materials are exposed at frequent intervals, rising to a maximum height of 8 or 10 feet above the water. Lithologically these materials resemble in all respects the laminated sands and clays of the Black Creek formation exposed in the bluffs of Cape Fear and Neuse rivers.

At Snow Hill no exposures of Cretaceous materials were observed along the immediate river banks. Professor Kerr,[1] however, observed such exposures, as shown by the following quotation: "And at Snow Hill, in Lenoir County, on Contentnea Creek, is a line of bluffs on the south side of the stream, several hundred yards in length, and 20 to 40 feet high, the lower portion of which to the height of 10 or 12 feet is a Cretaceous sandy marlyte, filled with shells, . . ." At the time visited the water was several feet higher than extreme low stage, and it may be the outcrops referred to were thus concealed; or vegetation may have since taken possession of the slopes. However, in a ravine near an old schoolhouse, in the scarp bordering a swamp to the west of town, a small fossiliferous exposure was found in which were collected a large number of fossils, including the larger part of the species described by Conrad in Kerr's report, to which reference has just been made. The matrix here consists of dark green, glauconitic, argillaceous sand or sandy clay. The fossil layer is perhaps 10 to 15 feet above medium low-water level in Contentnea Creek. In 1891 a collection was made by Dr. T. W. Stanton from the same horizon somewhere along this scarp to the west of town. These have not previously been studied or reported upon. The list of fossils as given below has been compiled from Conrad's list, from a list furnished by Gabb,[2] from Dr. Stanton's collection, and from the recent collection made by the writer.

[1]N. C. Geol. Surv. Report, Pt. I, 1875, pp. 147-149.

[2]Acad. Nat. Sci., Proc., Philadelphia, 1876, pp. 276, 324.

U. S. G. S. LOCALITY Nos. 785 AND 5348, KERR'S REPORT, 1875, GABB'S LIST AND STANTON'S COLLECTION. LOCALITY—SNOW HILL, N. C.

Hamulus major Gabb.
Serpula cretacea (Conrad).
Nucula n. sp. (aff. *N. percrassa* Conrad).
Leda sp. indet.
Cucullaea carolinensis Gabb.
Nemodon eufalensis Conrad.
Nemodon brevifrons Conrad.
Barbatia (Plagiarca) lintea Conrad.
Barbatia (*Plagiarca*) *carolinensis* Conrad.
Trigonoarca (Breviarca) umbonata Conrad.
Trigonoarca triquetra Conrad.
Trigonoarca (*Breviarca*) *perovalis* Conrad.
Trigonoarca (*Breviarca*) *carolinensis* Conrad.
Trigonoarca n. sp.
Glycymeris congesta (Conrad).
Inoceramus proximus Tuomey?
Gervillia sp.
Pteria petrosa (Conrad).
Ostrea sp.
Gryphaea sp.
Exogyra ponderosa Roemer.
Trigonia n. sp.
Pecten n. sp.
Lima oxypleura (Conrad).
Lima reticulata Forbes.
Anomia linifera Conrad.
Anomia lintea Conrad.
Anomia n. sp.
Mytilus condecoratus Conrad.
Mytilus nasutus Conrad.
Lithophaga carolinensis (Conrad).
Inoperna carolinensis Conrad.
Cymella bella Conrad.
Veniella conradi (Morton).
Etea carolinensis Conrad.
Eriphyla conradi (Whitfield).
Crassatellites carolinensis Conrad.
Crassatellites pteropsis Conrad.
Lucina glebula Conrad.
Brachymeris alta Conrad.
Tenea parilis Conrad.
Arena carolinensis Conrad.
Cardium eufaulense Conrad.
Cardium carolinensis Conrad.
Cardium (related to *C. alabamense* Gabb).
Protocardium carolinensis Conrad.
Cyprimeria depressa Conrad.
Cyprimeria densata (Conrad).
Aphrodina regia Conrad.
Cyclothyris alta Conrad.
Cyclothyris carolinensis Conrad.
Linearia (*Lyothyris*) *carolinensis* Conrad.
Linearia (probably new species) (*a*).
Linearia, n. sp. (*b*).
Legumen planulatum (Conrad).
Leptosolen biplicata Conrad.
Baroda carolinensis Conrad.
Hercedon ellipticus Conrad.
Oena plana Conrad.
Cymbophora lintea (Conrad).
Corbula crassiplica Gabb.
Corbula carolinensis Conrad.
Corbula n. sp.
Pholas n. sp.
Pholas sp. indet.
Dentalium?
Cadulus obnutus (Conrad).
Ataphrus kerri Gabb?
Chemnitzia?
Trichoptropis sp. indet.
Callonema carolinensis Conrad.
Gyrodes crenata Conrad.
Lunatia sp. indet.
Turritella quadrilira Johnson.
Anchura n. sp. (incorrectly identified as *A. rostrata* Morton by Conrad).
Pugnellus densatus Conrad?
Pyropsis sp. indet.
Liopeplum thoracica Conrad.
Placenticeras placenta De Kay.
Lamna texana Roemer.
Portheus sp. indet. (possibly *P. molussus*). Identified by J. W. Gidley.

The above list includes about 69 or more distinct species of invertebrate remains. This is the largest number yet obtained from any single

locality in North Carolina. That the horizon should be regarded as occupying a position lower than the Peedee sand is indicated by the conspicuous absence of such forms as *Ostrea larva* Lamarck, the typical forms of *Ostrea subspatulata* Forbes and *Exogyra costata* Say, and *Belemnitella americana* Morton, and by the presence of a considerable number of forms which are not known to occur in the Peedee formation or its equivalents, but which are found at numerous other localities in the upper part of the Black Creek formation and its equivalents. Of these the following are the more common: a new species of *Nucula* related to *N. percrassa* Con., *Trigonoarca triquetra* Conrad, *Exogyra ponderosa* Roemer, *Crassatellites carolinensis* Conrad, and *Corbula carolinensis* Conrad. Of the total number of species included in the above list, twenty or more have not previously been reported from other than this locality, although collections from some of the North Carolina localities which are described for the first time in this report, all of which occur in the upper part of the Black Creek formation, include a few of these species.

At Snow Hill and in the immediate vicinity the Black Creek beds, which as far as observed do not rise more than 15 or 20 feet above water level, are overlain unconformably by Miocene sands and clays.

The next exposure observed on Contentnea Creek revealing Cretaceous strata was at a point about 1 mile below the Snow Hill bridge. The section is given as follows:

SECTION 1 MILE BELOW SNOW HILL, RIGHT BANK.

Pleistocene:	FEET.
Loamy sand, grading down into coarse, loose sand with a gravel band at base	9
(Unconformity.)	
Cretaceous (Black Creek formation):	
Dark green, very sandy, glauconitic, micaceous clay	2

For several miles below this there are occasional low exposures of Cretaceous greensand or marine clay, but with the exception of some soft casts no fossils were observed.

At 27½ miles above the mouth of the stream, right bank, a poorly exposed bluff reveals only Miocene sands.

Within the next one-half mile there are several low occurrences of characteristic marine Cretaceous sands and clays belonging to the Black Creek formation. Figure 13, p. 142, shows the undulating character of the Cretaceous surface as it appears in a bluff above milepost 26.

At milepost 25, 6 miles below Snow Hill, left bank, the following forms were collected from a 4-foot exposure of greensand, the lower

portion of which, where it passed beneath the water, is filled with an abundance of fragile, fragmentary shells, with some perfect though fragile specimens, as follows:

U. S. G. S. LOCALITY No. 4142.

Exogyra ponderosa Roemer.
Trigonia n. sp. (same as at Snow Hill, N. C.)
Pecten simplicius Conrad.
Anomia n. sp.
Cyprimeria depressa Conrad.
Corbula crassiplica Gabb.
Bone fragment.

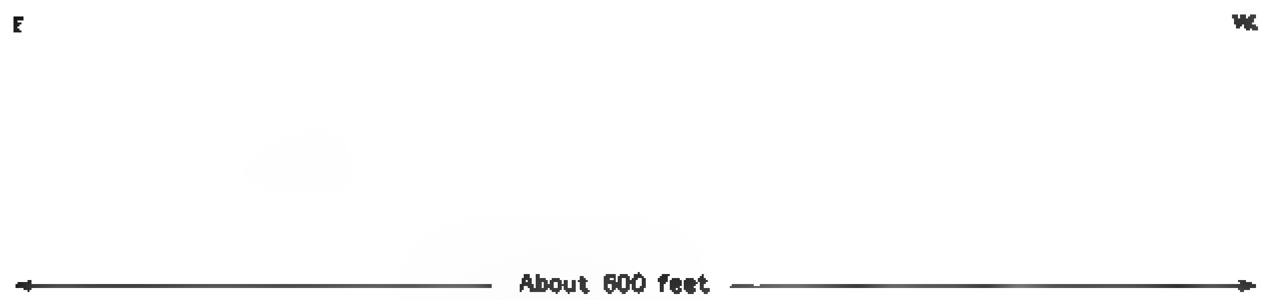


FIG. 13.—Sketch showing the undulating surface of the Black Creek formation overlain by Pleistocene deposits; Contentnea Creek, above milepost 26.

The presence of *Exogyra ponderosa* Roemer and of the *Trigonia* indicates that this horizon should be regarded as occupying a position about the same as that at Snow Hill.

Tar River exhibits the beds of the formation interruptedly from near Parker Landing, 12 miles above Greenville, to Randolph Landing, 6 miles above Greenville, Winterville quadrangle. (See sketch map of Tar River, Fig. 7, p. 101.)

The first exposure to be seen in descending the river is at a low bluff about one-fourth mile above Parker Landing. Here the Black Creek beds, which consist of dark to black laminated, lignitic clays, with fine micaceous sand partings, containing iron sulphide concretions, rest with unconformable relations upon Patuxent beds. A detailed section is given on page 103.

The next occurrence is about one-eighth mile below Parker Landing. At the base of this section a few feet of Patuxent clay appears above the water, overlain by several feet of poorly exposed Black Creek materials. These consist of laminated, dark to black clay, with partings and thin layers of micaceous sand, containing an abundance of lignite in the form of seams and comminuted particles, iron sulphide concretions, and occasional small pieces of amber. In certain of the layers and seams plant remains occur in considerable numbers. The forms listed below were collected:

Araucaria bladenensis Berry.
Araucaria Jeffreyi Berry.
Chondrophyllum Nordenskioldi Heer.
Eucalyptus Geinitzi (Heer) Heer.
Sequoia Reichenbachi (Gein) Heer.
Malapoenna horrellensis Berry.
Myrica cliffwoodensis Berry
Sequoia minor Velen.
Cephalotaxospermum carolineanum Berry?

At Center Bluff Landing, 9 miles above Greenville, fairly typical laminated materials were observed rising about 2½ feet above water level.

The greatest thickness of Black Creek beds occurring in one exposure on Tar River is at Blue Banks Landing. (See Plate IX, B, opposite p. 209.) The section is described as follows:

SECTION AT BLUE BANKS LANDING, 7 MILES ABOVE GREENVILLE, RIGHT BANK.

	Feet.
Pleistocene (Wicomico formation):	
Very coarse, light yellowish to white, arkosic sand	8
(Unconformity.)	
Miocene:	
Sand and clay layers	20-25
(Unconformity.)	
Cretaceous (Black Creek formation):	
Dark green, glauconitic, finely micaceous, argillaceous sand	4-9
Stratified, dark green to black, finely micaceous, arenaceous clay, containing some finely comminuted vegetable matter	4.5
Dark green, glauconitic, finely micaceous and arenaceous, calcareous clay, containing fossils	6
Dark green, finely micaceous, argillaceous glauconitic, calcareous sand, containing fossils	4

The following fossils were obtained from the fossiliferous portion of the above section:

U. S. G. S. LOCALITY Nos. 4144 AND 5347—BLUE BANKS LANDING, TAR RIVER, N. C., 7 MILES ABOVE GREENVILLE, N. C.

Bryozoa, encrusting.
Serpula cretacea (Conrad).
Hamulus major Gabb.
Hamulus squamosus Gabb.
Nucula n. sp. (aff. N. *percrassa* Conrad).
Leda (probably n. sp.) (*a*).
Leda (probably n. sp.) (*b*).
Cucullaea carolinensis Gabb.
Nemodon eufalensis Conrad.
Nemodon brevifrons Conrad.
Trigonoarca (Breviarca) umbonata Conrad.
Inoceramus proximus Toumey?
Gervillia ensiformis Conrad?
Ostrea n. sp.
Gryphaea sp.
Exogyra ponderosa Roemer.
Trigonia eufalensis Gabb.
Pecten simplicius Conrad.
Pecten n. sp.
Lima oxypleura (Conrad)?
Lima reticulata Forbes?
Anomia n. sp. (same as at Snow Hill).
Cymella bella Conrad.
Veniella conradi (Morton).
Crassitellites carolinensis Conrad.
Lucina glebula Conrad.
Cardium eufaulense Conrad.
Cardium sp. indet.
Isocardia n. sp.
Cyprimeria depressa Conrad.
Aphrodina?
Legumen planulatum (Conrad).
Cymbophora lintea (Conrad).
Corbula crassiplica Gabb.
Corbula carolinensis Conrad.
Corbula sp. indet.
Pholas cf. P. cithara Morton.
Gyrodes, sp. indet.
Anchura n. sp. (the same as at Snow Hill).
Baculites sp. indet.
Placenticeras placenta De Kay.
Undetermined pelecypods and gastropods.
Lamna texana Roemer.

Of the 35 or more determinable species enumerated in the above list, at least 25 are identical with species present at the Snow Hill locality. The evidence seems to be reasonably conclusive that the Snow Hill and Blue Banks Landing horizons are approximately synchronous.

About one-fourth mile below Blue Banks Landing a dark-green clay which contained a few fossils of the Black Creek formation was observed exposed to a height of 6 feet above water level.

A poor exposure of dark-green sand was observed at Randolph Landing 6 miles above Greenville, and this was the last place at which the Black Creek beds were seen in descending the river.

South of Cape Fear River there are but few exposures of Black Creek materials within the limits of the State. The lack of natural exposures is due to the fact that the stream incisions are shallow, and consequently the valley slopes are gentle and covered with vegetation.

The descriptions given by well owners and drillers of the materials penetrated in various borings in western Bladen and the southeastern half of Robeson counties furnish evidence, however, of the widespread occurrence of the Black Creek formation at shallow depths beneath the surface in these areas.

The buried coastward extension of the Black Creek formation has been recognized in two deep well borings. The first of these is at the Clarendon Waterworks plant at Wilmington, where the thickness amounts to 389 feet, extending from a depth of 720 feet to granite at 1,109 feet below the surface. The correlation is based upon the occurrence of *Ostrea cretacea* Morton at several horizons between the top and bottom of the strata indicated (see well section, p. 163). The second well is at Fort Caswell, near the mouth of Cape Fear River (p. 169), where a thickness of 400 feet of supposed Black Creek beds makes up the section from a depth of 1,140 feet to basement rocks at 1,540 feet below the surface. This correlation is based partly upon the occurrence of *Ostrea cretacea* Morton, which was found at two horizons, namely, 1,200-1,237 feet, and 1,365-1,380 feet, respectively. The strata not included between these horizons are largely of marine origin, and it seems best to tentatively regard them as belonging to the Black Creek formation.

The equivalency of the Black Creek formation as described by Earle Sloan in South Carolina with the "Bladen" formation has been proven by the discovery of the characteristic "Bladen" species *Araucaria bladenensis* in typical laminated materials at a locality 3 or 4 miles north of Florence, Florence County, a few hundred yards above the mouth of a small branch of Black Creek.

PEEDEE SAND.

Name.—The name Peedee was proposed by Edmund Ruffin[1] in 1843. It is derived from Great Peedee River, which crosses the eastern part of South Carolina from northwest to southeast. The terrane described by Ruffin under this name is essentially the same as that for which Earle Sloan[2] employed the name "Burches Ferry marls" in 1907. The exposure at Burches Ferry on Great Peedee River, which is Sloan's type section, is mentioned by Ruffin as one of the typical occurrences of the Peedee "bed." Ruffin's name, therefore, has priority over Sloan's. Both the lithologic and paleontologic character of this terrane are such as to indicate its equivalency with the division in North Carolina which the writer[3] in 1907 designated the "Ripley" formation.

The latter term is inappropriate, however, for, as the result of recent investigations, it has been found that the Peedee is the equivalent of only the upper part of the Ripley formation of Alabama, the equivalent of the lower part of that formation being included in the Black Creek ("Bladen") formation of this report.

Definition.—Exposures of the strata of this formation occur in a belt to the east and southeast of that of the Black Creek formation. As in the case of the Black Creek formation, the widest part of the belt is in the southern counties in the Cape Fear River region, where it reaches or perhaps exceeds 37 miles. To the north of Cape Fear River it extends in a north-northeasterly direction, the most northerly known occurrence being at Greenville in Pitt County. To the south of Cape Fear River it extends into South Carolina in a southwesterly direction with approximately the same width as in the Cape Fear River region, to and beyond Great Peedee River, where it disappears beneath the overlapping Eocene beds of the Charleston basis. (See geological map, Plate XVII, in pocket.)

The counties in which outcrops have been observed are as follows: Pitt, Greene, Lenoir, Duplin, Pender, Bladen, New Hanover, Columbus, and Brunswick.

The Peedee ("Burches Ferry") sand rests with conformable relations upon the Black Creek ("Bladen") formation. The relation of its upper surface to overlying Tertiary and Quaternary deposits is everywhere one of unconformity.

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[1]Report of the Commencement and Progress of the Agricultural Survey of South Carolina, Columbia, S. C., 1843 (esp. pp. 7, 24-27).

[2]Handbook of South Carolina, issued by the State Department of Agriculture, Commerce and Immigration, 1907, chapter 5, pp. 77-145.

[3]Johns Hopkins University Circular, No. 7 (whole No. 199), 1907, pp. 93-99.

In the vicinity of Wilmington and northeastward at least as far as Neuse River, Eocene strata have been shown to occupy more or less disconnected basin-like depressions in the undulating Cretaceous surface. To the eastward of this portion of the belt the Eocene thickens and probably forms a continuous sheet, as shown by well records. Beneath this sheet the Peedee beds pass coastward, becoming deeper and deeper beneath the surface for an unknown distance. From the South Carolina line northeastward to Neuse River, thin, more or less discontinuous sheets of Miocene and Pliocene deposits occur resting unconformably upon the Peedee formation, except where the above-mentioned Eocene strata intervene. In Greene and Pitt counties Miocene beds probably intervene continuously between the Peedee surface and the overlying Pleistocene deposits. Throughout the belt of outcrop of the Peedee formation wherever the above-mentioned Tertiary strata are absent the Peedee beds are overlain by thin, surficial Pleistocene deposits.

The great mass of the materials of the Peedee formation consist of dark-green or gray, finely micaceous, more or less glauconitic and argillaceous sands, many layers of which are calcareous and some of which are sufficiently calcareous to form an impure limestone. Irregular concretionary masses of impure calcium carbonate occur in places. These are either scattered irregularly through the sands, or are arranged in layers parallel to the bedding, producing nodular-like bands along the river bluffs. Such concretions have been observed as large as 4 or 5 feet in their longest diameter. Dark marine clays are present to some extent interstratified with the sand beds. The materials as a whole are quite compact. Fossils, principally invertebrates, occur either scattered irregularly through the deposits or arranged in layers 1 to 3 or more feet in thickness. Where the lime carbonate of the shells remain, as is commonly the case, the materials may be classed as shell marl. The content of glauconite in the greensands of North Carolina appears to be less than that of the greensand marls of New Jersey. A number of analyses of the greensands are given by Ebenezer Emmons in his report of the North Carolina Geological Survey, 1858, entitled "Agriculture of the Eastern Counties," pp. 89-100.

The strike of the formation may be assumed to be approximately parallel to the direction of the belt of outcrop. To the north of Cape Fear River this direction is north-northeast and south-southwest. In the region of Cape Fear River it swings around northeast-southwest and extends into South Carolina in that direction.

The Peedee beds have a gentle southeastward dip, the amount of which can be determined only approximately. Calculations based upon

surface observations along Cape Fear River and upon data obtained from the deep well borings at Wilmington and Fort Caswell, give results pointing to a dip of between 20 and 25 feet to the mile.

The greatest known thickness of the formation in North Carolina is that presented by the section of the Fort Caswell well (p. 169). The base of the Eocene is at 254 feet and the lowest occurrence of characteristic Peedee fossils is at 1,140 feet, making a thickness of 886 feet of undoubted Peedee beds. In the deep well at Wilmington the Peedee beds were penetrated from the surface to a depth of 720 feet (p. 163).

That a comparable thickness of Peedee beds would probably be encountered in wells sunk near the coast elsewhere in North Carolina is indicated by records of wells at Charleston, S. C., and at Norfolk, Va. At the former place marine Cretaceous strata were recognized from a depth of about 600 feet to 1,980 feet, and at the latter from 715 to 1,320 feet. It is probable that in each case the greater part of the Cretaceous strata penetrated should be referred to the Peedee sand.

The formation is quite generally fossiliferous. Marine invertebrates constitute the bulk of the contained fossil remains. Among vertebrates, however, sharks' teeth are not uncommon, and fragments of bones occur at rare intervals. The invertebrates occur either scattered irregularly through the deposits or aggregated in layers. In places the shells have been preserved, but elsewhere the shell material has been dissolved away, leaving casts of impure lime, clay, sand, pyrite, or phosphate. Collections were made at many places, lists of which will be found in the detailed accounts of localities.

The table opposite shows the geographic distribution and range of the invertebrate species of the Peedee formation in North Carolina.

Detailed Sections.—The bluffs of Cape Fear River furnish the best series of exposures of the Peedee formation in the State. These occur from Donohue Creek Landing, 50⅓ miles above Wilmington, to near the mouth of Black River. At several places in this distance the Peedee beds are overlain by a few feet of Miocene or Pliocene sand or marl, but for the greater part of the distance a surficial Pleistocene terrace covering rests directly upon the Cretaceous surface. (See sketch map of Cape Fear River, Plate I, opposite p. 88.)

A detailed section of the exposure at Donohue Creek Landing is given below.

SECTION AT DONOHUE CREEK LANDING, 50⅓ MILES ABOVE WILMINGTON.

Pleistocene:	FEET.
Yellow loam, grading down into sand with gravel band at base 1 foot in thickness	7
(Unconformity.)	

[illegible]

[illegible] Feet

[illegible]

The fossils [illegible] at the above locality, all of which occur above [illegible] are as follows:

[illegible]

[illegible]	*Cardium* [illegible] Weller.
[illegible]	[illegible] sp. [illegible]
[illegible] Weller?	[illegible] M. and H.
Ostrea [illegible]	[illegible] sp.
[illegible]	*Volutoderma?*
[illegible]	Crocodilian tooth.
[illegible]	Fish vertebra.
[illegible] *costata* Say.	*Lamna texana* Roemer.
[illegible] Morton.	*Otodus appendiculatus* Agassiz.
[illegible] Conrad.	*Corax falcatus* Agassiz.
[illegible] Conrad.	

[illegible] Creek Landing to Magnolia Landing, which is 15½ [illegible] Wilmington, the Peedee formation is exposed in many [illegible] to a maximum height of 40 to 50 feet above the water level. The materials consist of compact, dark green or dark gray, fine [illegible], more or less glauconitic sand, as a rule somewhat argillaceous and in many places calcareous, with occasional indurated layers. The compact nature of the beds renders them resistant to erosion, so that the bluffs are in most places steep and in some places even vertical. In many of the sections a few fossils occur scattered irregularly through the deposits and an occasional fossiliferous layer occurs.

Photo by E. W. Berry.

A.—Exposure of the Peedee sand overlain by Pliocene and Pleistocene strata, Cape Fear River, near Bryants Landing, 27 miles above Wilmington, N. C.

Photo by E. W. Berry.

B.—Exposure of the Peedee sand overlying conformably the Black Creek formation, Cape Fear River, Donohue Creek Landing, 50 1-3 miles above Wilmington, N. C.

Miocene shell marl occurs resting directly upon the upper surface of the Cretaceous at the following places: Robinsons and Browns landings between mileposts 50 and 49, and Black Rock Landing, milepost 37. Pliocene shell marl occupies a similar position at Neills Eddy Landing, milepost 28, and at Bryants Landing, milepost 27.

Lists of fossils from various localities below Donohue Creek Landing, all of which belong to the Peedee sand, are given below:

U. S. G. S. LOCALITY Nos. 3356 AND 5419—CAPE FEAR RIVER, N. C., ROBINSONS LANDING, 49½ MILES ABOVE WILMINGTON, N. C.

Cucullaea antrosa Morton.
Arca?
Ostrea subspatulata Forbes.
Ostrea sp.
Ostrea plumosa Morton.
Ostrea larva Lamarck.
Exogyra costata Say.
Trigonia eufalensis Gabb?
Anomia argentaria Morton.
Anomia lintea Conrad.
Cardium sp.
Lamna texana Roemer.
Otodus appendiculatus Agassiz.

U. S. G. S. LOCALITY No. 3353—CAPE FEAR RIVER, N. C., KELLYS COVE, 46 MILES ABOVE WILMINGTON, N. C.

Ostrea subspatulata Forbes.
Ostrea sp.
Exogyra costata Say.
Exogyra costata var. ***cancellata*** Stephenson,
Anomia argentaria Morton.

U. S. G. S. LOCALITY Nos. 3150, 4157, 5370—CAPE FEAR RIVER, N. C., INDIAN WELLS LANDING, 41 MILES ABOVE WILMINGTON, N. C.

Ostrea subspatulata Forbes.
Ostrea sp.
Ostrea plumosa Morton.
Exogyra costata Say.
Exogyra costata var. ***cancellata*** Stephenson.
Gryphaea vesicularis Lamarck.
Anomia argentaria Morton.
Cardium sp.
Otodus appendiculatus Agassiz.

U. S. G. S. LOCALITY No. 4154—CAPE FEAR RIVER, N. C., DANIELS LANDING, 40 MILES ABOVE WILMINGTON, N. C.

Ostrea larva Lamarck.
Ostrea plumosa Morton.
Exogyra costata Say.
Gryphaea vesicularis Lamarck.
Anomia argentaria Morton.

U. S. G. S. LOCALITY No. 3448—CAPE FEAR RIVER, N. C., KINGS BLUFF, 38½ MILES ABOVE WILMINGTON, N. C.

Ostrea subspatulata Forbes.
Exogyra costata Say.
Gryphaea vesicularis Lamarck.
Aphrodina?
Gyrodes sp.
Turritella sp.

U. S. G. S. LOCALITY Nos. 3149 AND 5371—CAPE FEAR RIVER, N. C., BLACK ROCK LANDING, 37 MILES ABOVE WILMINGTON, N. C.

Cucullaea sp.
Exogyra costata Say.
Exogyra costata var. ***cancellata*** Stephenson.
Gryphaea vesicularis Lamarck.
Anomia argentaria Morton.
Crassatellites sp.
Cardium spillmani Conrad.
Cardium sp.
Gyrodes sp.
Rostellites sp.
Anchura?
Belemnitella americana Morton.
Reptilian tooth.

U. S. G. S. LOCALITY No. 3452—CAPE FEAR RIVER, N. C., HUDLERS LANDING, 30½ MILES ABOVE WILMINGTON, N. C.

Ostrea subspatulata Forbes.	Fine specimen of crab, probably undescribed.
Exogyra costata Say.	
Anomia argentaria Morton.	

U. S. G. S. LOCALITY No. 3451—CAPE FEAR RIVER, N. C., NEILLS EDDY LANDING, 28 MILES ABOVE WILMINGTON, N. C.

Ostrea subspatulata Forbes.

(NO NUMBER.) LOCALITY—CAPE FEAR RIVER, N. C., BRYANTS LANDING, 27 MILES ABOVE WILMINGTON, N. C.

Ostrea subspatulata Forbes.

U. S. G. S. LOCALITY No. 4155—CAPE FEAR RIVER, N. C., WANETS LANDING, 25½ MILES ABOVE WILMINGTON, N. C.

Ostrea subspatulata Forbes.

The last exposure of Peedee beds observed in descending the river was at Magnolia Landing. The section is as follows:

SECTION AT MAGNOLIA LANDING, 15½ MILES ABOVE WILMINGTON, RIGHT BANK.

	Feet.
Pleistocene: (poorly exposed)	6-7
(Unconformity.)	
Cretaceous (Peedee sand):	
Hard, fossiliferous, limestone rock	1.5
Dark blue to greenish, argillaceous sand, with some limestone concretions 1 foot or more in diameter	2
Concealed to water's edge	1.5

A list of the fossils from the preceding locality is subjoined:

U. S. G. S. LOCALITY No. 4151.

Cassidulus sp.	*Exogyra costata* Say.
Echinoid (a regular form).	*Gryphaea vesicularis* Lamarck?
Membranapora?	*Lima* sp.
Serpula cretacea (Conrad).	*Anomia argentaria* Morton.
Cucullaea antrosa Morton.	*Paranomia?*
Arca sp.	*Cardium spillmani* Conrad.
Inoceramus sp.	*Cardium dumosum* Conrad?
Ostrea subspatulata Forbes.	*Cardium* sp.
Ostrea tecticosta Gabb.	*Aphrodina* sp.
Ostrea sp.	

On Black River several exposures of typical Peedee materials have been observed between Goff Landing, 41¼ miles, and Point Caswell, 36 miles, respectively, above Wilmington. (See sketch map of Black River, Fig. 13, p. 124.) These are all low occurrences, the beds nowhere rising more than 2 or 3 feet above water level. The overlying materials

are of Pleistocene age. Specimens of *Exogyra costata* Say were obtained at Goff Landing, and, near Sparkleberry Landing, 39¾ miles above Wilmington, specimens of *Exogyra costata* Say and *Exogyra costata* var. *cancellata* Stephenson were obtained.

The banks of Northeast Cape Fear River exhibit the Peedee formation from Deep Bottom Bridge, 75 miles above Wilmington, where it is overlain unconformably by supposed Eocene beds, at numerous places to a point about 44 miles above Wilmington, and at Hilton Park, Wilmington. After the first exposure seen in descending the river where only a few feet of Peedee strata appear at the base of a 40-foot section made up principally of Eocene (?) beds, the occurrences are all low, not exceeding 10 or 15 feet, the overlying materials constituting Pleistocene terrace deposits. Between the last point mentioned and Wilmington the Peedee beds were not observed above water level, being transgressed for a part if not all the distance by Eocene deposits. At Hilton Park, Wilmington, however, the Cretaceous again appears, overlain at this particular place by Pleistocene terrace deposits. Beyond this point the formation passes finally beneath the Eocene, having been detected only in well borings at points nearer the coast. (See sketch map of Northeast Cape Fear River, Fig. 14, p. 152.)

With one or two exceptions the observations on Northeast Cape Fear River were made at a time when the water was 6 or 8 feet higher than the normal stage. Peedee beds were first observed in descending the stream near Deep Bottom Bridge, about 75 miles above Wilmington. The river here swings against a bluff 25 to 40 feet in height, along whose base it continues for about ⅜ of a mile to a point ⅛ mile below Deep Bottom Bridge. The face of the bluff is partially free from vegetation at several places, but the best section is at the lower end of the bluff, where it is exposed from top to bottom. The section in detail is as follows:

SECTION BELOW DEEP BOTTOM BRIDGE, LEFT BANK.

	Feet.
Pleistocene:	
Yellowish loam, grading down into light drab, sandy clay, mottled with pink and red	10
Eocene?	
Alternating sand and clay layers with a pebble band at base	29
(Unconformity.)	
Cretaceous (Peedee sand):	
Dark green, coarse, glauconitic, micaceous sand with many small white pebbles as large as peas, containing *Pecten* (?), a few small sharks' teeth and numerous individuals of *Ostrea subspatulata* Forbes in a thin layer (U. S. G. S. Loc. No. 4134). This layer first appears above the water's edge a few rods above where the section was taken and gradually rises to a height of 4 or 5 feet a few rods below	1½

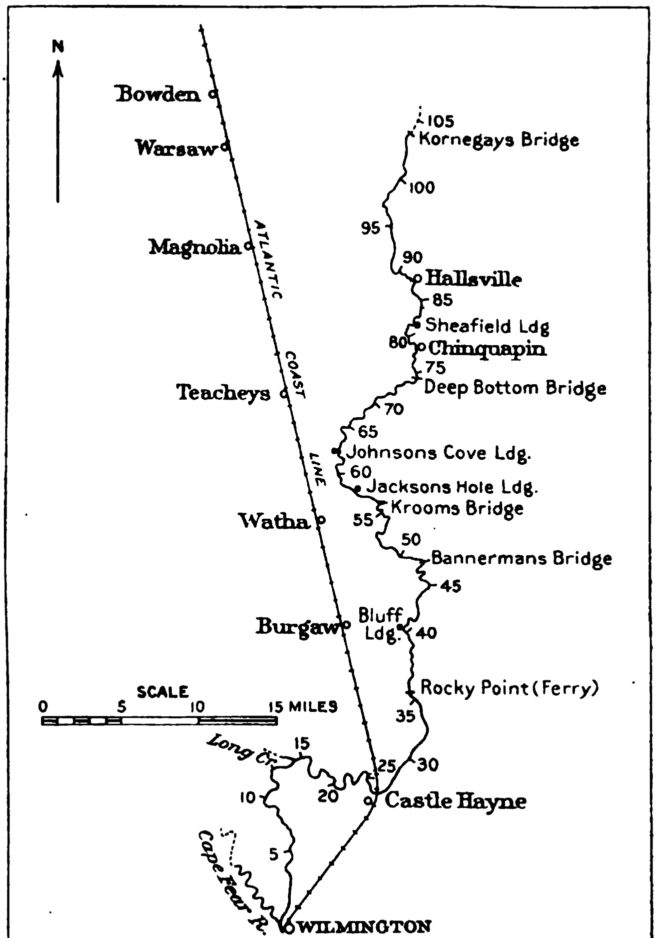

FIG. 14.—Sketch map of part of Northeast Cape Fear River, N. C.

The Peedee greensand was seen only at and near where the section was taken, the only materials appearing at other portions of the bluff belonging to the Tertiary and Pleistocene.

Between Deep Bottom Bridge and milepost 62 a number of low exposures, not exceeding 5 feet, of Peedee materials were observed, consisting of dark green, glauconitic, micaceous, more or less argillaceous sand, certain layers of which were indurated to a firm rock. A few characteristic fossils were collected at two of these exposures, as follows:

U. S. G. S. LOCALITY No. 4131—NORTHEAST CAPE FEAR RIVER, N. C., ABOUT 67½ MILES ABOVE WILMINGTON, N. C., RIGHT BANK.

Exogyra costata Say.
Gryphaea vesicularis Lamarck.

U. S. G. S. LOCALITY No. 4161—NORTHEAST CAPE FEAR RIVER, N. C., 66½ MILES ABOVE WILMINGTON, N. C.

Bryozoa.
Exogyra costata Say.
Gryphaea vesicularis Lamarck?
Pecten tenuitestus Gabb.
Lima pelagica (Morton).
Anomia argentaria Morton.
Paranomia scabra Morton.

At Johnsons Cove, 61¾ miles above Wilmington, the following section was taken:

SECTION AT JOHNSONS COVE, RIGHT BANK.

	Feet.
Pleistocene:	
Loose, light sand	6
(Unconformity.)	
Cretaceous (Peedee sand):	
Firmly indurated, dark gray, calcareous, glauconitic sand, containing many fossils	2
Dark green, argillaceous, micaceous, rather coarse sand, containing a few fossils	7

A list of the forms obtained at the above described locality is given below.

U. S. G. S. LOCALITY No. 4133.

Ostrea plumosa Morton.
Ostrea tecticosta Gabb.
Ostrea larva Lamarck.
Exogyra costata Say.
Gryphaea sp.
Pecten sp.
Lima reticulata Forbes.
Lima pelagica Morton.
Turritella sp.
Belemnitella americana Morton.

A section was studied at milepost 61, left bank, as follows:

SECTION AT MILEPOST 61, LEFT BANK.

	Feet.
Pleistocene:	
Loose white sand	8
(Unconformity.)	

	Feet.
Cretaceous (Peedee sand):	
Dark green glauconitic sand	1
Greenish-gray, glauconitic and calcareous standstone, containing numerous fossils	1½
Dark greenish-gray, glauconitic sand, containing a few fossils	2

A list of the fossils obtained is subjoined:

U. S. G. S. LOCALITY No. 4130.

Ostrea subspatulata Forbes.	*Gryphaea vesicularis* Lamarck.
Ostrea tecticosta Gabb.	*Lima reticulata* Forbes.
Ostrea plumosa Morton.	*Anomia argentaria* Morton.
Exogyra costata Say.	*Belemnitella americana* Morton.

At about 58¾ miles above Wilmington a section was examined as follows:

SECTION 58¾ MILES ABOVE WILMINGTON, RIGHT BANK.

	Feet.
Pleistocene:	
Loamy sand grading down into argillaceous sand	9
(Unconformity.)	
Cretaceous (Peedee sand):	
Dark greenish-gray, glauconitic, micaceous, slightly argillaceous sand with two indurated layers, one at base and the other a few feet above base, each 1 foot thick. Fossiliferous	9
Light gray, soft, glauconitic, calcareous sand with an indurated layer 1 foot at base and another ½ foot thick a few feet above base. Fossiliferous	9

The following fossils were collected at this locality:

U. S. G. S. LOCALITY No. 4149.

Bryozoa.	*Trigonia thoracica* Morton?
Inoceramus sp.	*Pecten?*
Ostrea subspatulata Forbes.	*Lima* sp.
Ostrea tecticosta Gabb.	*Anomia argentaria* Morton.
Exogyra costata Say.	*Gyrodes* sp.
Gryphaea vesicularis Lamarck.	*Turritella trilira* Conrad.
Trigonia eufalensis Gabb.	*Belemnitella americana* Morton.

Jacksons Hole is near milepost 58. This locality was visited in the early spring of 1906 when there was a medium low stage of water. There was then exposed about 3 feet of Peedee greensand indurated at the water's edge to a firm rock, while just beneath the indurated layer and covered by the water there was a soft shell marl. The whole was fossiliferous, and the following forms were obtained:

U. S. G. S. LOCALITY No. 4140.

Bryozoa.	*Exogyra costata* Say.
Ostrea subspatulata Forbes.	*Gryphaea vesicularis* Lamarck.
Ostrea tecticosta Gabb.	*Anomia argentaria* Morton.
Ostrea sp.	*Belemnitella americana* Morton.

The Jacksons Hole locality is probably not more than a mile from the Lewis Creek locality near South Washington, visited by Hodge in 1840 and later by Lyell in the early forties.

Lewis Creek enters the Northeast Cape Fear a short distance above Jacksons Hole. At a point about ½ mile above its mouth, near the site of an old water mill, a few fossils were obtained, all of which were found at the Jacksons Hole locality, and it is probable that the two localities represent exactly the same horizon. It is also possible that this is the exact locality visited by Hodge and later by Lyell. The following forms were obtained:

U. S. G. S. LOCALITY No. 4168.

Ostrea subspatulata Forbes.	*Anomia argentaria* Morton.
Ostrea tecticosta Gabb.	*Belemnitella americana* Morton.
Exogyra costata Say.	

Continuing down the river, occasional low exposures of Peedee greensand were observed to a point about 44 miles above Wilmington. A few specimens of *Ostrea subspatulata* Forbes (U. S. G. S. Loc. No. 4166) were obtained at Krooms Bridge, milepost 56; but otherwise no fossils were seen.

Between the occurrence at milepost 44 and Hilton Park, Wilmington, there is no place where Peedee beds are known to rise above water level in the river. Sections at points 41¼ and 30⅛ miles above Wilmington, respectively, show only Eocene strata. However, at Lanes Ferry (Rocky Point), 35 miles above Wilmington, and at Castle Hayne, materials which would correspond to the Peedee beds as here defined have been reported by Dr. Stanton[1] in rock quarries at the base of Eocene limestone, and it is probable that at no place in this region is the surface of the formation more than a few feet below low-water level.

The lowest point on the Northeast Cape Fear at which the Peedee beds have been observed in surface exposures is at Hilton Park at the northern edge of the city of Wilmington, New Hanover County. The following section was made a few rods below the pump station of the Clarendon Waterworks Company:

SECTION AT HILTON PARK, WILMINGTON, N. C.

	FEET.
Pleistocene:	
Coarse, light gray to yellowish, loose, somewhat loamy sand soil..	1½
Yellowish-brown, medium-grained sand	4
Concealed	5
(Unconformity.)	

[1] Am. Geol., vol. 7, pp. 333-334.

Cretaceous:	
Peedee sand (?):	FEET.
Fine grained, light gray to white, almost pure sand, slightly argillaceous in places, more compact than the Pleistocene above, and delicately mottled with chocolate tints and in places with light yellow. Probably a leached-out phase of marine Cretaceous materials	8
Peedee sand:	
Dark green, compact, finely micaceous, glauconitic clay	2
Dark green, very compact, glauconitic, very calcareous, arenaceous, slightly micaceous clay, indurated in places with lime cement to hard rock layers or concretions; contains characteristic fossils; partially concealed by high tide	4-5

The lowest Cretaceous layer in the section appears interruptedly for several hundred yards along the left bank of the river below the pump station. The following forms were obtained:

U. S. G. S. LOCALITY No. 4143.

Hemiaster sp.	*Pecten simplicius* Conrad.
Bryozoa.	*Lima* sp.
Serpula sp.	*Anomia argentaria* Morton.
Cucullaea sp.	*Crassatellites?*
Perna sp.	*Panopea decisa* Say.
Exogyra costata Say.	*Nautilus dekayi* Morton.

Exposures of Peedee beds occur interruptedly on Neuse River from near Williams Landing, 52 miles above New Bern, to within a few miles of the mouth of Contentnea Creek. With the exception of two occurrences of Eocene strata which are indicated on following pages, the deposits observed overlying the Peedee beds along this stream are of Pleistocene age. A detailed account of the Neuse River exposures is given below. (See sketch map of Neuse River, Fig. 4, p. 96.)

Two miles above the steamboat landing at Kinston (51¾ miles above New Bern), near Williams Landing, a dark green, argillaceous greensand of the Peedee formation forms a bluff 12 or 15 feet in height along the left bank, and this overlain by several feet of Pleistocene material. The following species, several of which are characteristic of the Peedee sand, were collected, occurring mostly in a layer near the base:

U. S. G. S. LOCALITY No. 4152.

Ostrea subspatulata Forbes.	*Gryphaea vesicularis* Lamarck.
Ostrea larva Lamarck.	*Lima reticulata* Forbes.
Ostrea plumosa Morton.	*Anomia argentaria* Morton.
Exogyra sp.	

Below the steamboat landing at Kinston, Peedee greensand rises several feet above the water on the left bank, and at the next bend below similar materials may be seen at low water for some distance along the right bank.

From the wagon bridge above milepost 48 to the Norfolk Southern Railroad bridge below milepost 47 there are almost continuous exposures of compact greensand along the right banks of the stream, rising in places 8 or 10 feet above the water, the undulating surface being everywhere overlain by a surficial covering of Pleistocene terrace deposits. At the latter bridge *Exogyra costata* Say and *Anomia* were collected. (U. S. G. S. Locality No. 4132.)

A low exposure of greensand was seen at 45½ miles above New Bern. At 44¾ miles an exposed thickness of 7 or 8 feet of Peedee greensand is overlain by 2 feet of shaly clay with a pebble band at base probably of Eocene age.

The last exposure of marine Cretaceous observed in descending the river was at a ferry 34⅔ miles above New Bern, or 3⅓ miles above the mouth of Contentnea Creek. The strata are not well revealed, the examination being made in the ditch along the side of the road leading down to the ferry. The section obtained is as follows:

SECTION AT FERRY 34⅔ MILES ABOVE NEW BERN, RIGHT BANK.

	Feet.
Pleistocene:	
Sand and loam poorly exposed	15
Eocene:	
Thin-bedded shale with conglomerate band at base	7
(Unconformity.)	
Cretaceous (Peedee sand):	
Dark green, very compact, arenaceous, glauconitic, micaceous clay, containing numerous shells and casts	11
Concealed to water's edge	3

The fossils listed below were collected from the greensand.

U. S. G. S. LOCALITY Nos. 4169 AND 4137.

Hemiaster sp.	*Exogyra costata* Say.
Bryozoa.	*Pecten simplicius* Conrad.
Serpula sp.	*Lima* sp.
Nucula sp.	*Anomia argentaria* Morton.
Cucullaea sp.	*Turritella vertebroides* Morton.
Ostrea tecticosta Gabb.	*Belemnitella americana* Morton.
Ostrea plumosa Morton.	Crab claws.

That a very marked unconformity exists between the Cretaceous and Eocene is shown by the fact that a few rods below where the section

[illegible] water's [illegible] Peedee [illegible] the water. The Eocene [illegible]

The [illegible] Contentnea Creek [illegible] Peedee beds at a number of [illegible] Snow Hill, Greene County. [illegible] Contentnea Creek, Fig. 4. [illegible]

[illegible] Contentnea Creek, right bank. [illegible] A layer of [illegible]

SECTION [illegible] CONTENTNEA CREEK [illegible] BANK.

	Feet
Pleistocene:	
[illegible]	12
Miocene:	
Light gr[illegible] yellow in places with [illegible]	20
Cretaceous (Peedee sand):	
[illegible]	3

Be[tween] here and the bridge at Hookerton there are a number of [illegible] exposures of Peedee greensand. A short distance below this bridge [the] greensand is overlain by 12 feet of light colored, stratified sand, [simil]ar to the supposed Miocene sands described in the preceding section. At several points below this low exposures of greensand were observed, and at milepost 20, right bank, the greensand rises about 12 feet above the water. At the base of this latter section the following forms were collected:

U. S. G. S. LOCALITY No. 4148.

Nucula n. sp. (aff. *N. percrassa* Conrad).
Ostrea sp.
Ostrea plumosa Morton.
Trigonia (probably a new species).
Anomia argentaria Morton.
Cardium sp.
Bone fragment.

One mile above Edwards Bridge (which is just on the western edge of the Ayden quadrangle) the Peedee strata show a slight variation from the usual lithologic character. The section is as follows:

SECTION 1 MILE ABOVE EDWARDS BRIDGE, LEFT BANK.

	Feet.
Pleistocene:	
Loam and sand with thin gravel band at base, rusty brown in lower 2 feet	6
(Unconformity.)	
Cretaceous (Peedee sand):	
Coarse, very green, very glauconitic sand with a mealy texture, containing the highest percentage of glauconite of any of the greensands observed in the State	4
Layer of concretions of all sizes up to several inches in diameter, consisting of greensand cemented with lime	1
Dark brownish, argillaceous, glauconitic sand	3

Between here and Edwards Bridge the greensand appears in several low exposures. Below Edwards Bridge nothing was seen until milepost 7 was reached, between which point and Grifton the greensands and clays of the Peedee appear at a number of places rising not more than 6 or 7 feet above the water.

At milepost 6, left bank, 1½ miles above Grifton, *Ostrea subspatulata* Forbes and *Exogyra costata* Say were collected from upper Peedee beds. (U. S. G. S. Locality No. 4153.)

The most northerly occurrence of the Peedee formation is at Greenville, in Pitt County. Although no surface exposures have been seen by those who have recently worked in that vicinity, the existence of the beds there are known from an account given by Conrad in 1871.[1] He describes the occurrence of the characteristic fossil *Belemnitella americana* Morton in Cretaceous sand in the bottom of a marl pit beneath a Miocene shell bed. From this account it is reasonably certain that in places at least in the vicinity the Peedee beds are present at no great depth beneath the surface.

South of Cape Fear River valley the only surface occurrence of Peedee strata known within the State is on the north shore of Waccamaw Lake in Columbus County. To the east of the pumping station of the Atlantic Coast Line Railroad a low bluff is formed by the outcrop of an indurated layer of Miocene shell marl or limestone. The base of the Miocene is revealed at one place only, which is at the west end of the bluff near the pumping station. Immediately beneath the indurated layer there is a loose conglomerate consisting of rounded pebbles and irregular nodules of phosphate, internal phosphate casts of

[1] Amer. Jour. Sci., 3d ser., vol. 1, pp. 468-469, 1871.

gastropods and pelecypods, shells of *Exogyra* and guards of *Belemnitella,* all in a matrix of yellowish brown, calcareous sand. The shore near-by is strewn with casts, phosphate nodules, etc., which appear to have been washed from this conglomerate. The following forms were collected in place in the conglomerate: *Belemnitella americana* Morton, and undetermined casts of pelecypods and gastropods. (U. S. G. S. Locality No. 4051.) In addition, a number of forms which had been washed from this conglomerate were picked up loose on the shore, as follows:

U. S. G. S. LOCALITY No. 4146.

Cucullaea antrosa Morton.
Cucullaea sp.
Exogyra costata Say.
Gryphaea vesicularis Lamarck.
Anomia argentaria Morton.
Veniella sp.
Crassatellites sp.
Cardium sp.
Cyprimeria sp.
Gyrodes sp.
Rostellites sp.
Belemnitella americana Morton.
Fish vertebra.

The deposit is a basal conglomerate of the Miocene, the fossils being derived from the underlying Cretaceous. Beneath the conglomerate there is exposed at low water 2 or 3 feet of compact, dark gray, calcareous and micaceous sand, referable to the Peedee formation. This sand is exposed along the shore for a few rods only.

Sets of well samples have been examined from a number of wells in the southeastern part of the State in which Peedee beds were penetrated, and from these the sections given on the following pages have been prepared. The figures to the left in the sections indicate sample numbers.

Section of well at Bolton, Columbus County, N. C., owned by the Waccamaw Land and Lumber Company, and drilled in 1906 by Lowry and Faulkner, prepared from samples furnished by Mr. John D. Lowry.

		Thickness in Feet.
Pleistocene:		
1.	Missing	1- 10
2.	Pale yellowish, very sandy clay	10- 30
3.	Yellow, coarse, very argillaceous sand	30- 40
Miocene:		
4.	Light gray, calcareous sand with numerous shells	40- 50
Cretaceous (Peedee sand):		
5.	Gray, very calcareous, arenaceous clay	50- 70
6.	Same as No. 5	70- 90
7.	Similar to Nos. 5 and 6, but a shade darker	90-110
8.	Greenish-gray, very calcareous, arenaceous clay	110-130
9.	Similar to No. 8, but a shade lighter	130-140

		Thickness in Feet.
10.	Gray, very calcareous, arenaceous clay, with a tinge of yellow	140-150
11.	Greenish-gray, very calcareous, arenaceous clay and pieces of hard, gray, calcareous sandstone	150-160
12.	Gray, very calcareous, argillaceous clay	160-180
13.	Greenish-gray, calcareous, argillaceous sand	180-200
14.	Clean, loose, fine-grained, glauconitic, micaceous, slightly calcareous sand	200-220

At Newberlin the Peedee formation was encountered at a depth of 40 feet, as shown by the following section, which was prepared from samples furnished by the owner:

SECTION OF WELL AT NEWBERLIN, N. C., FARM No. 24, OWNED BY THE CAROLINA TRUCKING DEVELOPMENT COMPANY.

		Thickness in Feet.
Pleistocene:		
1.	Red, sandy clay	0- 10
2.	Buff, coarse, argillaceous sand	10- 20
3.	Coarse, yellow sand	20- 30
Miocene? (Pliocene?):		
4.	Coarse sand and gravel with numerous fragments of shells.	30- 40
Cretaceous (Peedee sand):		
5-22.	Dark gray clay, more or less sandy and finely micaceous in the different samples. In samples 17 and 19 there are concretions of iron pyrites and in sample No. 19 a phosphate nodule	40-220
	(There is no sample representing materials from 220 to 232 feet.)	
23A.	Gray, calcareous sandstone	232-234
23B.	Loose, fine-grained, very glauconitic sand, water-bearing.	234-236
24.	Coarse, rather clean sand with small fragments of shells.	236-238

Section of well at St. Helena, 2½ miles south of Burgaw, Pender County, N. C. (Italian colony near A. C. L. Railroad), from samples furnished by the Carolina Trucking Development Company, Wilmington, N. C.

		Thickness in Feet.
Pleistocene:		
1.	Gray clay	0- 10
Miocene:		
2-6.	Shell marl and gray or greenish-gray, fossiliferous sand...	10- 60
Cretaceous (Peedee sand):		
7.	Dark gray, finely micaceous, glauconitic sand and sandy clay, apparently laminated	60- 70
8.	Fine, loose, light gray, micaceous, glauconitic sand	70- 80
9.	Same as preceding, but darker gray	80- 90
10.	Dark gray, slightly argillaceous, finely micaceous, glauconitic sand	90-100

		Thickness in Feet.
11.	Light gray, fine, loose sand	100-110
12-13.	Light gray, very coarse, loose sand with small pieces of gray sand rock, and many small water-worn fragments of sharks' teeth, plates, etc.	110-130
14-18.	Fine, loose, light gray, micaceous sand	130-180
19.	Very coarse, gray, slightly argillaceous, calcareous sand	180-190
20.	Marl, consisting of coarse, gray, slightly argillaceous sand, and containing *Ostrea larva* Lamarck, *Paranomia scabra* (Morton), pelecypod fragments, mainly *Ostrea*, sharks' tooth, sp. indet, etc.	190-200
21.	Sandy, argillaceous marl with one large chunk of gray, calcareous clay. The marl contains a large amount of fragmentary shell material, including *Exogyra costata* Say, *Ostrea*, etc.	200-210
22.	Marl, similar to preceding, containing *Exogyra costata* Say.	210-220

Section of well near Castle Hayne, owned by Carolina Trucking Development Company, from samples furnished by the company.

		Thickness in Feet.
Pleistocene:		
1.	Sample missing.	
Eocene:		
2.	Coarse yellow sand and gravel and fragments of gray sandstone	at 26
(Correlation uncertain).		
3.	Light yellow, fine-grained, calcareous, slightly micaceous sand (probably ground rock) and pieces of hard, gray, calcareous sandstone	at 33
Cretaceous (Peedee sand):		
4.	Pieces of hard, gray, calcareous sandstone, clear quartz sand, and small pebbles of quartz and phosphate	at 43-10 in.
5.	Missing.	
6.	Gray, fine-grained, calcareous, slightly micaceous sand	83- 98
7.	Dark gray, fine-grained, calcareous, micaceous sand, with thin flakes of still darker calcareous clay	98-112
8-9.	Dark gray, fine-grained, calcareous, micaceous, argillaceous, slightly glauconitic sand	112-132
10.	Dark gray, finely arenaceous, calcareous clay	132-142
11-13.	Similar to No. 10, but sand content slightly coarser and slightly glauconitic	142-182
14-20.	Dark gray, fine-grained, calcareous, micaceous, slightly glauconitic and slightly argillaceous sand	182-285
21-23.	Dark gray (darker than preceding), medium fine grained, calcareous, micaceous, slightly glauconitic, slightly argillaceous sand	285-315
24-28.	Clear, loose, medium-grained, micaceous sand, a few shell fragments in No. 24, and a small undetermined oyster in No. 25	315-365

Section of well at plant of Clarendon Waterworks Company, Hilton Park, Wilmington, N. C., in part from samples on exhibition in glass cases at the State Museum, Raleigh, N. C., where they were examined and described by the writer, and in part from the drillers' records. The fossils were determined by Dr. T. W. Stanton:

		Thickness in Feet.
Cretaceous:		
Peedee sand:		
1.	Gray, coarse sand	0- 10
2-3.	Yellowish-brown, argillaceous sand	10- 30
4.	Hard, gray, calcareous sandstone rock containing shell impressions	30- 40
5.	Pale yellow, calcareous sand, with small pieces of crushed sandstone, containing *Pecten* sp., *Ostrea* sp., etc.	40- 50
6.	Loose, gray sand, containing casts of *Cardium*	50- 60
7.	Hard, gray, calcareous sandstone	60- 70
8-35.	Gray, calcareous, micaceous sand, varying slightly in content of lime and mica and also in color and coarseness. Contains Echinoid fragments, *Ostrea larva*, *Ostrea tecticosta*, *Ostrea* sp., *Gryphaea vesicularis*, *Exogyra costata*, *Exogyra* sp., *Anomia argentaria*, *Cyprimeria* sp., *Aphrodina tippana?*, *Cymbophora lintea*, fragments of other bivalves, sharks' teeth	70- 350
36-39.	Light gray, loose, calcareous, micaceous sand, containing *Anomia argentaria*	350- 390
40.	Washings, depth 330 to 421 feet, consisting of broken shells and hard, gray, calcareous sandstone. Contains indurated fragments of *Ostrea subspatulata*, *Exogyra costata*, *Baroda carolinensis*, *Cyprimeria depressa*, several undetermined mollusks and sharks' teeth.	
41.	Same as samples Nos. 36 to 39. Contains *Exogyra costata*, *Ostrea* sp., undescribed species of *Avicula* or *Gervillia*, *Anomia*, etc.	390- 400
42-46.	Fine, dark gray, calcareous, argillaceous, slightly glauconitic sand	400- 450
47.	Light gray, loose, calcareous sand, containing fragments of *Ostrea*	450- 460
48.	Gray, calcareous, micaceous, glauconitic sand with chunks of gray clay, containing fragments of *Ostrea* and sharks' teeth	460- 470
49.	Washings, depth 421-485 feet, consisting of broken shells, sharks' teeth, and gray, calcareous sandstone. Contains *Ostrea tecticosta*, *Anomia*, lignite, etc.	
50-52.	Loose, gray, glauconitic, slightly micaceous sand, with chunks of gray clay, containing lignite, *Ostrea tecticosta*, *Ostrea* sp., *Exogyra costata*, *Anomia argentaria*, *Anomia* sp., *Cardium* sp., *Corbula* sp., sharks' teeth, and fragments of turtle shells	470- 500
53.	Washings, depth 495-500 feet, consisting of hard, gray, calcareous, fossiliferous sandstone.	

		Thickness in Feet.
54.	Fine gray, calcareous, glauconitic sand, containing *Ostrea tecticosta* and sharks' teeth........................	500- 510
55-58.	Washings, depth 500-538 feet, consisting of hard, gray sandstone, laminated gray clay, lignite, shells, etc. Contains *Inoceramus* fragment, *Ostrea larva*, *Ostrea tecticosta*, *Ostrea* sp., *Exogyra costata*, *Exogyra costata* var., *Anomia argentaria*, vertebra of fish, and sharks' teeth.	
59.	Gray, calcareous, glauconitic sand.....................	510- 520
60.	Loose, light gray, calcareous, micaceous sand with chunks of gray clay......................................	520- 530
61-63.	Washings, depth 518-538, 520-540, and 500 feet, respectively, consisting of gray, calcareous sandstone, gray, laminated clay, iron sulphide concretions, shells, etc. Contains lignite, *Cassidulus subquadratus*, *Glycymeris*, *Ostrea tecticosta*, *Exogyra costata*, *Anomia* sp., *Cardium eufalense*, *Lunatia*, fragments of turtle shells, etc.	
64-66.	Gray, calcareous, glauconitic sand, argillaceous in samples Nos. 64 and 66. Contains *Ostrea* sp., *Exogyra costata*, *Lithophagus* sp.	530- 560
67.	Washings, depth 538-558 feet, consisting of gray, calcareous sandstone, laminated clay, iron sulphide concretions, shells, etc. Contains lignite, *Ostrea tecticosta*, *Exogyra costata*, *Cardium eufalense*, and sharks' teeth.	
68.	Loose, light gray, glauconitic sand......................	560- 570
69-70.	Washings, depth 560-575 feet, consisting of gray, fossiliferous sandstone, gray, laminated clay, shells, etc. Contains lignite, Bryozoa, *Ostrea tecticosta*, *Anomia argentaria*, *Cardium*, *Pugnellus densatus*.	
71.	Loose, light gray, glauconitic sand....................	570- 580
72.	Washings, depth 575-785 feet, consisting of gray sandstone, laminated clay, shells, lignite, etc. Contains resin, *Inoceramus cripsii*, *Ostrea tecticosta*, *Anomia* sp., and fragments of turtle shell.	
73.	Loose, light gray, glauconitic, micaceous sand..........	580- 590
74-75.	Washings, depth 585-595 feet, consisting of laminated clay, iron sulphide concretions, etc. Contains lignite, *Ostrea tecticosta*, *Exogyra costata*, *Anomia* sp., *Lunatia* sp., sharks' teeth, vertebra of fish, and fragments of turtle shell.	
76.	Light gray, loose, micaceous, glauconitic sand...........	590- 600
77.	Washings, depth 595-598 feet, similar to samples Nos. 74-75. Contains *Ostrea tecticosta*, *Exogyra costata*, *Anomia* sp., sharks' teeth.	
78-89.	Light gray, finely micaceous, glauconitic sand, argillaceous in some samples, varying in coarseness, glauconitic content and color. Contains *Ostrea tecticosta*, sharks' teeth.	600- 720

Black Creek formation:		THICKNESS IN FEET.
90.	Light gray, very calcareous, slightly glauconitic sand, possibly a ground-up rock	720- 730
91-92.	Washings, depth 720-735 feet, consisting of gray, calcareous rock and broken shells, some of the shells being stained brown with iron oxide. Contains *Ostrea cretacea*, *Gryphaea vesicularis*, *Placenticeras* sp., etc.	
93-100.	Fine, light greenish and yellowish glauconitic, calcareous, argillaceous, finely micaceous sand, containing *Ostrea cretacea*	730- 820
101.	Washings, depth 817-820 feet, consisting principally of broken *Ostrea* shells, some of which are stained brown with iron oxide. Contains *Ostrea cretacea*, *Anomia* sp., sharks' teeth, etc.	
102.	Similar to samples Nos. 93-100	820- 830
103-110.	Gray, calcareous, finely micaceous clay, containing *Ostrea* fragments, and *Anomia*	830- 910
111-112.	Mostly fragments of shells, with some lumps of gray, calcareous clay, containing *Ostrea* fragments, *Exogyra*, etc.	910- 930
113.	Coarse, brownish, micaceous, very calcareous sand, containing *Ostrea cretacea*	930- 940
114.	Clean, loose, very micaceous sand	940- 950
115.	Washings, depth 956 feet, consisting of angular quartz pebbles up to ½ inch in diameter, varying in color from white to pale yellow and pink, and *Ostrea* fragments.	
116-119.	White to pale yellow and pinkish, coarse, slightly micaceous sand, with angular grains	950- 990
120.	Washings, depth 992 feet, consisting of coarse sand, angular pebbles, and lignite.	
121-122.	Coarse, yellow sand, with indurated chunks cemented with arkosic material. Lignite in sample No. 121	990-1000
123.	Washings, depth 1031-1034, consisting of gray sandstone, quartz pebbles, shells and lignite. Contains *Serpula*, *Ostrea cretacea*, *Ostrea* sp., etc.	
124.	Washings, depth 1061-1065 feet, similar to preceding, containing *Ostrea cretacea*, *Exogyra* sp., *Cardium* sp., etc.	

[Lithologic samples from 1,000 feet to the bottom of the well (except washings) are lacking in the museum collection, but from the original samples fossils were taken as follows:

1037-1088	*Ostrea cretacca*, *Exogyra* sp. Resembles young of *Exogyra ponderosa*.
1104-1105	Lignite, *Ostrea cretacea*, *Exogyra* sp.

	THICKNESS IN FEET.
1105-1113 { Mostly decomposed granite, but contains one fragment of large *Ostrea*.	

The remainder of the section is taken from the driller's written description of the materials penetrated.]

Red sand	1000-1011
Yellow sand	1011-1013
Yellow sand and gravel	1013-1015
Oyster shells, shale rock, mud	1015-1031
White clay and sand mixed	1031-1034
Blue clay	1034-1053
Gravel and green clay, soft rock	1053-1061
Soft rock, and shells	1061-1065
Sand	1065-1075
Black sand	1075-1081
Red and white clay	1081-1083
Sand and shells	1083-1087
Red clay and sand mixed	1087-1088
Red clay	1088-1095
Sand and small pebbles	1095-1104
Red clay and hard rock, which looks like granite	1104-1109
Basement Rock:	
Granite	1109-1330

A brief account of the Hilton Park well by Prof. J. A. Holmes is given in *Science*, new series, vol. 9, 1900, pp. 128-130.

On the basis of the evidence obtained from the fossils, the strata penetrated in the upper 720 feet are regarded by Dr. Stanton as the equivalent of the Ripley formation, and the remaining 389 feet down to the basal granite at a depth of 1,109 feet as the equivalent of the Eutaw formation. Beds representing the Lower Cretaceous seem to be absent. The reference of the lower beds to the Eutaw was made on the ground of the occurrence of the fossil *Ostrea cretacea* Morton. According to the present classification of the North Carolina deposits, the portion of the section which he correlated with the Ripley formation should be referred to the Peedee sand and the remainder or Eutaw portion of the section to the Black Creek formation.

Section of well at northeast corner of Third and Nunn streets, Wilmington, N. C., owned by John D. Bellamy, Jr., from samples furnished by John D. Lowry, contractor:

	THICKNESS IN FEET.
No sample (probably *Pleistocene*)	1- 35
Miocene:	
1-2. White to light gray sand, fossiliferous in sample No. 2	35- 58

(*Eocene* does not appear to be present.)

	THICKNESS IN FEET.
Cretaceous (Peedee sand):	
3. Light gray, fine-grained, calcareous, slightly micaceous sand. Numerous very small fragments of shells.......	60- 62
4. White, medium-grained, loose, clean quartz sand, slightly calcareous	62- 75
5. Light gray, fine-grained, calcareous, slightly micaceous sand	75- 90
6. Similar to No. 5, but a trifle lighter in color. Contains some small fragments of shells..........	90- 101
7. This sample consists principally of fragments of gray, hard, very calcareous sandstone. With these are slightly rounded grains of quartz sand and numerous fragments of shells mostly resembling oyster shells. Some of the rock fragments have Cardium-like impressions upon them. (Lithologically, this sample resembles Peedee material at a depth of 40 feet in the Wilmington well)............	101- 115

Section of well No. 2, Winter Park Garden, 3 miles east of Wilmington, N. C., near the tracks of the C. L. and P. Company's electric road to Wrightsville, owned by Henry McMillan, from samples furnished by Winter Park Garden Company.

	THICKNESS IN FEET.
Pleistocene:	
1. White, coarse, gravelly quartz sand. One pebble an inch long, probably a partially decomposed igneous rock......	32- 44
2. Very coarse, gravelly quartz sand..........	44- 50
Miocene:	
3. Shell marl with a matrix of gravel and sand..............	50- 54
Eocene:	
4-7. White to light gray fossiliferous sand, with an abundance of bryozoan remains..........	54- 78
White sandy limestone, with numerous bryozoan remains..	78- 83
Cretaceous (Peedee sand):	
9. Dark green, calcareous, finely arenaceous and micaceous, and slightly glauconitic clay. Assigned to marine Cretaceous because of its lithologic resemblance to materials of that age in this region..........	83- 88
10. Gray, calcareous sand (doubtless the ground-up rock) and numerous fragments of hard, calcareous sandstone. A few bryozoan fragments which have probably fallen down from above, shell fragments, and one shark's tooth. Driller's description: hard rock..........	88- 95
11. Sample is similar to No. 10. Driller's description: rock and sand	95- 100
12. Gray, calcareous sand, some fragments of rock of the same nature, a few shell fragments. Driller's description: sand-rock	100- 110
13. Same as No. 12. Driller's description: sand-rock..........	110- 120

		THICKNESS IN FEET.
14.	Gray, very calcareous, very sandy clay, or very argillaceous sand	120- 130
15.	Gray, medium-grained, very calcareous, glauconitic sand, with some fragments of gray, calcareous sand-rock, and some small shell fragments. Driller's description: rock.	130- 140

Section of well at Masonboro Sound, 7 or 8 miles southeast of Wilmington, N. C., owned by W. L. Parsley, from samples furnished by John D. Lowry, contractor:

		THICKNESS IN FEET.
Pleistocene:		
1.	Medium-grained, clean, white quartz sand	at 15
Eocene:		
2-11.	Alternating layers of gray, calcareous sand and white fossiliferous limestone, containing numerous bryozoan remains	25- 155
Cretaceous (Peedee sand) (?):		
12.	Coarse, gray, calcareous sand and rock (probably in alternate layers). Contains many fragments of shells, probably for the most part *Ostrea*, and a few bryozoan remains which may have fallen down from above	155- 165
13.	(?) (Not labeled) Similar to sample No. 12. A larger percentage of loose sand. Occasional grains of glauconite. (This sample is needed to complete the section, and it probably belongs here)	165-187?

Section of well at Quarantine Station, located about 1 mile east of Southport, N. C., in center of Cape Fear River estuary, prepared from samples forwarded to the State Survey by the officers in charge:

		THICKNESS IN FEET.
Pleistocene:		
1-5.	Loose beach sand with shells and fragments of shells, probably Pleistocene. Sample No. 4 is argillaceous	15- 40
6.	Light bluish-gray, iron-stained coquina rock, consisting of shells in very fragmentary condition cemented with lime.	40- 45
7-9.	Loose sand with shells and fragments of shells similar to samples Nos. 1 to 5	45- 60
10-11.	Chunks of gray, calcareous clay, pieces of light-blue coquina rock and numerous well-preserved shells of Pleistocene age	60- 70
Eocene:		
12-39.	Bluish-gray and cream-colored fossiliferous limestone. Contains an abundance of bryozoan remains	70- 215
40-47.	Light gray, calcareous, fossiliferous sand	215- 265
Cretaceous (Peedee sand):		
48-67.	Dark gray, very argillaceous, very calcareous, fine-grained sand. (Could be classed as very arenaceous clay.) The	

		THICKNESS IN FEET.
	different samples vary slightly in color, some having a bluish-gray tinge, and others a dark brownish tinge. The lower samples become slightly less argillaceous. Finely comminuted shell fragments occur in sample No. 54......	265- 365
68-74.	Gray, calcareous, glauconitic sand, slightly argillaceous in upper samples, becoming coarser and very glauconitic in lower samples	365- 400

Section of well at Fort Caswell, near the mouth of Cape Fear River, N. C., from samples furnished by the officer in charge:

		THICKNESS IN FEET.
Pleistocene:		
1.	Loose beach sand with small shell fragments..........	0- 30
2-3.	Gray, calcareous, sandy clay with well-preserved Pleistocene fossils, *Barnea*, *Crepidula*, *Nassa*, etc............	30- 45
4-6.	Loose, calcareous sand with numerous shell fragments and in sample No. 6 large fragments of Pleistocene fossils as follows: *Cardium*, *Teredo*, *Ostrea*, *Scutella*, *Crepidula*. Also, in sample No. 6, pieces of calcareous sand-rock, fragments of peat, iron crusts, and one fragment of crystalline rock, probably granite............	45- 78
Eocene:		
7-25.	Consists principally of yellow, calcareous, fossiliferous sand, with some clay. Sample No. 11 consists of white chalk-like rock (thickness 4 inches)................	78- 254
Cretaceous:		
Peedee sand:		
26-33.	Gray, very calcareous clay, with an admixture of soft sand in last two samples. *Serpula* casts in sample No. 32..	254- 418
34.	Gray, calcareous, very glauconitic sand................	418- 419
35-46.	Gray, calcareous clay, slightly sandy in some samples...	419- 678
46½.	Mixture of gray, calcareous clay, sand and fragments of shells; containing Bryozoa, *Ostrea* fragments, etc.....	678- 680
47.	Sample missing....................................	680- 690
48-48½.	Same as No. 46½, but contains impure lime concretions as large as 1 inch in diameter. Contains Bryozoa, *Ostrea* sp., etc..	690- 693
49-55½.	Gray, argillaceous, calcareous sand, with numerous small shell fragments. No. 50 contains fragments of gray, calcareous sand-rock. Samples 55 and 55½ contain *Ostrea* sp., etc....................................	693- 795
56-57.	Dark green, very glauconitic, calcareous sand...........	795- 880
58.	Mixture of chunks of dark green, glauconitic sand, and gray, calcareous sand	880- 896
59.	Coarse, gray sand, with small shell fragments..........	896- 899
59½.	Light gray, argillaceous limestone, with casts of pelecypods and gastropods. Contains *Cardium* sp., *Lunatia* sp., etc.	896- 899

		Thickness in Feet.
60-65½.	Gray, calcareous, finely micaceous clay, large pieces of shells of *Ostrea subspatulata* and *Exogyra* sp. in sample 65½	899-1140
Black Creek formation:		
66.	Light pinkish, plastic clay	1140-1160
67-68.	Samples missing	1160-1200
68½.	Gray, calcareous clay, with a mixture of quartz pebbles up to ½ inch in diameter and shell fragments. Contains Bryozoa and *Ostrea cretacea* (?), etc	1200-1237
69.	Clean, loose, slightly calcareous sand	1237-1253
70.	Sample missing	1253-1259
71.	Light gray, calcareous clay	1259
72-73.	Light to dark pinkish or reddish, finely laminated clay	1259-1322
74.	Light gray, calcareous clay, with an admixture of small quartz pebbles as large as birdshot	1326-1334
75.	Coarse, argillaceous, calcareous sand	1342-1365
76-76a.	Coarse sand and gravel with pebbles up to ⅓ inch in diameter. Also, pieces of gray, calcareous sand-rock and pieces of shells. Sample 76 contains Bryozoa, *Ostrea cretacea*, *Exogyra* sp., etc	1365-1380
77-78.	Very coarse sand, many of the grains as large as birdshot, with small particles of gray, calcareous clay, and with numerous fragments of shells	1380-1405
79-80.	Coarse sand, with a large percentage of small particles of gray calcareous clay, scattered grains of glauconite, and numerous shell fragments, among them encrusting bryozoans. Sample 80 contains Bryozoa	1405-1440
81.	Coarse, loose sand and fine fragments of crushed sandstone, filled with particles of iron oxide. Contains a few shell fragments	1440-1442
82-83.	Loose, white, medium-grained sand, with a few shell fragments	1442-1455
84.	Fine, dark gray, micaceous, slightly glauconitic sand	1455-1470
85-86.	Loose, gray, medium-grained slightly micaceous sand	1470-1490
87.	Fine, yellowish gray, glauconitic, micaceous sand	1490-1500
88.	Fine, dark gray, micaceous, slightly glauconitic sand	1500-1510
89.	Dark pinkish drab, arenaceous, micaceous clay	1510-1525
90.	Coarse, argillaceous sand and chunks of light gray and pink-mottled, coarsely arenaceous clay	1525-1532
91.	Very fine, gray, micaceous, glauconitic sand	1532-1540
Basement Rock:		
	A metamorphosed rock (possibly from an old eruptive?) having a very fine granular texture. Consists principally of interlocking quartz grains with considerable greenish mica flakes and grains of red iron oxide. There are also numerous grains of epidote and some chlorite. A stretched apatite crystal observed in one slide. (Description credited to Dr. Albert Johannsen)	1540-1543

The above well was drilled by W. H. Gray & Bros. of Chicago, Ill. Drilling was started on September 9, 1905, and the last sample was taken May 6, 1907. In a letter transmitting the samples, the method of drilling is described by T. T. Allard, the officer in charge at the time the well was begun, as follows: "The system of drilling is the rotary hydraulic. Water, in which a large quantity of clay has been thoroughly stirred, is pumped down to the bottom of the drill on the inside, and washed up the cuttings on the outside. The clay penetrates and seals the sand and prevents caving.

"The method so mixes the material as to render it difficult to obtain satisfactory samples of the thin strata."

The well is owned by the United States Government.

THE TERTIARY FORMATIONS.

BY BENJAMIN L. MILLER.*

HISTORICAL REVIEW.

By the earliest writers, Maclure, Olmsted, and others, no attempt was made to differentiate the strata of the Coastal Plain, but instead they were considered to constitute a unit which received the name of the "alluvial formation." In Europe certain deposits had received the name of Secondary and Tertiary, and in 1824 John Finch, in an article[1] entitled "A Geological Essay on the Tertiary Formations in America," ventured the statement that the "alluvial formation" of Maclure contained representatives of both of these divisions. Later writers recognized the division of Coastal Plain deposits into Cretaceous ("Secondary") and Tertiary strata, but as the separation was made on the basis of the lithology or at most the genera of the fossils preserved in the deposits, further subdivisions were impracticable, without more detailed studies of the fossils. At this stage Say, Conrad, and Lea began their paleontologic investigations of the Atlantic Coastal Plain. Conrad[2] in 1832 described a few fossils from New Bern, North Carolina, which he referred to the "Upper Marine" or "Upper Tertiary," while Lea, in his "Contributions to Geology," published in 1833, referred certain beds in Alabama to the Eocene as defined by Lyell in England. This is the first reference to Eocene strata in this country, and is, therefore, of much importance in the literature of the entire Coastal Plain, although no reference is made to the North Carolina deposits.

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*Except part on Lafayette formation, by L. W. Stephenson.

[1]Amer. Jour. Sci., vol. 7, 1824, pp. 31-43.

[2]Fossil shells of the Tertiary formations of North America, vol. 1, No. 1, 20 pp., 6 pls. Philadelphia, 1832.

In the decade following the publication of Lea's work the differentiation of the Tertiary was extended to other regions and the Eocene became generally recognized as distinct from the later Tertiary strata. In North Carolina the beds at Wilmington early received attention, while exposures along the Trent and Northeast Cape Fear rivers were mentioned.

It remained for Lyell, who had named and described the Tertiary divisions of Europe, to definitely determine the presence of similar strata in North Carolina. While in this country he visited many fossil localities in the State, and at Wilmington recognized the presence of deposits of both Eocene and Miocene age.[3]

Since Lyell's time there has never been any question regarding the presence of Eocene and Miocene strata in North Carolina, and early claims regarding the existence of Pliocene deposits have been substantiated by the later work of Dall. Emmons, in his geological report, published in 1858, and Kerr, in his report published in 1875, made important contributions to the knowledge of the Tertiary deposits of the State, summarizing the results of previous investigations. Clark, Stanton, Holmes, and others have described in later years many local sections in much detail.

Heilprin,[4] in 1883, proposed the name "Carolinian" for the Miocene deposits of the Carolinas, regarding them younger in age than the Miocene deposits of Virginia and Maryland, which he proposed to call "Virginian" and "Marylandian."

In 1890, Dall began the publication of his elaborate monographic study of the Tertiary fauna of Florida, in which he included descriptions of all of the known Tertiary fossils of the Atlantic Coastal Plain. In these studies, extending over a period of 13 years, he recognized the fact that the Miocene was capable of subdivision, and also clearly differentiated the Pliocene, regarding which much doubt had been expressed by others. No detailed study of the stratigraphy of the North Carolina Tertiary deposits had been made, however, up to the time that the United States Geological Survey, in coöperation with the North Carolina Geological and Economic Survey, began the present investigations in 1905, and no general article based on detailed stratigraphic work has thus far been published.

DIVISIONS.

The Atlantic Coastal Plain, as well as the Gulf Coastal Plain, has been found, on careful study, to be far less simple than it was formerly

[3]Travels in North America, etc. New York, 1845.
[4]Proc. Phila. Acad. Nat. Sci., vol. 24, 1883, pp. 150-186.

believed to be. Instead of a single unit, as regarded by Maclure, it has been found, on careful investigation, to have had a complex history and to consist of many different formations based on differences in lithologic and paleontologic characteristics, and many of the formations are separated by marked unconformities. In Maryland, where the deposits of the Coastal Plain have been studied in great detail, 16 different formations have been recognized. Similar studies in New Jersey, Virginia, South Carolina, and the Gulf States have shown the Coastal Plain to consist of many units or formations.

In North Carolina the Eocene has thus far been considered a unit, and no formational names have been introduced. Recent studies, however, have shown that on the basis of its fossils and its lithologic characters, it is capable of division into at least two formations, and for these the names of Trent and Castle Hayne are proposed. It is not improbable that one or both of these may later prove to be synonyms of terms previously used to describe the same formations in South Carolina or Alabama, but, until such correlations have been definitely established, it seems best to use local names.

The possibility of dividing the Miocene of North Carolina into different formations was recognized by Dall, although he did not have the stratigraphic facts at hand to warrant such a separation. The field work that has been carried on by the United States Geological Survey in coöperation with the North Carolina Geological Survey during the past few years has furnished the necessary data for such division, and it is now proposed to refer the Miocene strata of North Carolina to three formations. The oldest formation is recognized as the equivalent of the St. Marys formation of Maryland and Virginia, which has been described in detail for the former State, while the younger Miocene strata are referred to the Yorktown formation, which receives its name from the town of Yorktown on the York River in Virginia, and the Duplin formation, which receives its name from Duplin County, where it is well developed in the "Natural Well." These formations are unlike, both lithologically and faunally, and, furthermore, are separated by unconformities.

The Pliocene of North Carolina is still somewhat indefinite, mainly for the reason that the paleontologic work has not progressed to a point where positive statements can be made. It is possible that the detailed study of the fossils may prove the existence of two marine Pliocene formations, though at present it seems best to refer all of these strata to a single formation, the Waccamaw.

It is recognized, however, that the Pliocene of the Cape Fear River is, in many respects, somewhat different from the deposits on the south side of the Neuse River in the vicinity of Croatan and Slocums Creek.

The former seems to be closely related to the Miocene in paleontologic characteristics, while the latter is more closely allied to the Pleistocene. The information in regard to the Neuse River localities is so meager that it seems inadvisable at the present time to establish a new Pliocene formation to include those beds. In fact, it seems highly probable that they may later be found to belong to the Pleistocene and correlated with the Simmons Bluff locality in South Carolina or the marine Pleistocene strata that underlie a considerable portion of the Great Dismal Swamp in Virginia and North Carolina. It is with these reservations that the Waccamaw is here made to include beds that seem to be somewhat unlike faunally. The Lafayette formation, which has been provisionally referred to the Pliocene, is discussed later.

EOCENE.

TRENT FORMATION.

Name.—The Trent formation receives its name from the Trent River, along which stream it is exposed from the vicinity of Trenton, Jones County, to near the junction of the Trent and Neuse rivers.

Definition.—The Trent formation consists of the basal beds of the Eocene in North Carolina, and is composed of calcareous marls, fossiliferous limestones, and fine-grained, siliceous sandstones deposited under marine conditions and extending inland from the coast south of the Neuse River to Wake, Moore, and Harnett counties.

The Trent strata rest upon an uneven inter- or post-Cretaceous erosion surface that at present has a gentle slope to the southeast. A few miles southeast of Raleigh and about 3 miles northeast of Spout Springs the deposits rest directly upon the uneven surface of the Lower Cretaceous rocks. These and some other small areas are isolated from the main body of the Trent and represent remnants that have resisted the agents of erosion which have removed strata of the same age that, probably, at one time covered a large portion of the Piedmont rocks in this State. Elsewhere the Trent formation overlies Cretaceous strata belonging to the Patuxent, Black Creek, and Peedee formations. In some places it can be plainly seen to occupy depressions in Cretaceous deposits, thus indicating the uneven erosion surface on which deposition took place when the Trent submergence occurred. One of the best examples of this unconformity is shown along the Neuse in the vicinity of Broadhurst Bridge (82¼ miles above New Bern). At this point exposures of Eocene limestone occur at several places for a distance of about 1½ miles with no Cretaceous strata showing beneath, but both upstream and downstream the marine Cretaceous rises to view.

Were not the Cretaceous and Eocene strata so nearly horizontal, such exposures might indicate synclinal folding, but the very small dip of the strata precludes any such possibility.

The Trent formation is overlain by deposits belonging to the younger formations. In the vicinity of Wilmington the Trent dips beneath the Castle Hayne deposits, though there are no known exposures where the two are represented in the same section, and therefore no evidence has been obtained in this way to determine whether the Trent and Castle Hayne formations are conformable or not, in those regions where both are present, although the evidence secured from well borings makes it probable that they are. Between Polloksville and New Bern, in some places along the Trent River near Trenton, and also in the vicinity of Mount Olive, this formation is directly overlain by the Yorktown formation, while in the vicinity of Goldsboro it seems to pass beneath the St. Marys deposits. However, in almost all the places where the Trent strata are exposed the overlying material consists of sands, gravels, and clays of the Pleistocene, which form the surficial covering of the greater part of the Coastal Plain in this State. With the possible exception of the Castle Hayne formation, the Trent is known to be unconformable with every formation that overlies it.

Lithologic Characters.—The Trent formation consists of various kinds of materials in different portions of the State. Primarily the deposits consist of light-colored calcareous marl that is either loose or locally consolidated. This is well shown in the section exposed in the right bank of the Trent River at White Bank Landing about 1½ miles below Trenton. In certain places the calcareous marl has been firmly indurated and forms a hard, compact limestone that, lithologically, closely resembles some of the Paleozoic limestones of the Appalachian region. This limestone usually contains many fossils, and in places the rock seems to have been largely formed of the shells of *mollusca, bryozoa,* and *echinoderms.* In certain places the shells are present, though in most places the shell particles have been entirely removed and the rock is either cavernous or contains many moulds or calcareous casts of the organisms that were originally present. Such limestones are exposed in many places along the Neuse and Trent rivers, but are particularly well developed at Spring Garden and Rock landings and in the Sarpony Hills on the Neuse River and at Rock Spring, White Rock Landing, in the vicinity of Trenton on the Trent River and at Jacksonville.

Near Olivers the limestone does not form a distinct bed, but there are irregular masses of limestone in a matrix of quartz sand, while at Biddle Landing on the Neuse River the limestone contains many fragments of shells mixed with considerable quartz sand.

The limestones from the Trent formation have been quarried for use as building stones, buhrstones, and for the manufacture of lime.

At Polloksville and near Olivers this formation contains beds of the gigantic oyster, *Ostrea georgiana,* many specimens of which are more than a foot in length. Some are said to measure more than 20 inches in their longest diameter. The shells are found in an extremely rotten condition that renders them valuable for fertilizing purposes.

In certain places the deposits of this formation contain small amounts of glauconite, black, water-worn, phosphatized pebbles, and fragments of sharks' teeth and other Cretaceous fossils. It seems probable that all of these materials have been derived from the underlying marine Cretaceous deposits which were worn away and redeposited by the waves during the time that the Trent formation was being laid down. A section in which these characters are shown is exposed along the Neuse River about 6½ miles below Kinston.

Some outliers of Eocene materials that are provisionally referred to the Trent formation in the vicinity of Raleigh consists of firmly indurated, siliceous shell rock. They were undoubtedly calcareous limestones originally, but have gradually been changed to their present character by the removal of the calcium carbonate and the deposition of siliceous matter in its place.

To determine the total thickness of the Trent formation is very difficult, for the reason that it occurs in isolated areas, for the most part, occupying depressions in the old Cretaceous surface, and thus far it has not been possible to determine whether these separated beds are contemporaneous or not. Where the strata are continuous for a considerable distance, as along the Trent River, the total thickness of the beds exposed is much greater. Later strata appear as one goes eastward, as the dip of the beds is in that direction. At Trenton a well record shows the formation to be 73 feet thick, while it seems probable that it is about 100 feet thick at Polloksville. Southeast of Wilmington, well borings show a total thickness of 140 feet of Eocene material, but the data are not sufficient to determine what part of the beds belong to the Trent and what portion to the Castle Hayne formation. From what we know of the two formations from outcropping strata the Trent seems to be much the thicker of the two and probably constitutes somewhat more than 100 feet of the combined Eocene strata.

The fossils of the Trent formation are especially abundant in many places and constitute the greater portion of the exposed strata. They are well preserved in most places, though certain strata contain only the moulds of the shells, with no part of the original animal remaining. The fossils belong to the *Mollusca, Molluscoidea,* and *Echinodermata* mainly.

Pelecypods and *Gastropods* are the common molluscan forms, and specimens of these are found in almost every exposure. The gigantic *Ostrea georgiana* that occurs in such abundance at Polloksville and near Olivers is one of the most interesting forms of this formation. It seems, however, to have had a very local distribution, so cannot be used to any great extent for purposes of correlation.

The most striking characteristics of the Trent fauna are the great quantities of bryozoan remains. Almost every outcrop of the formation will furnish specimens of this group, while in some places scarcely any other fossils occur. Spines and occasional tests of *Echinoids* are also common and are associated with the remains of the *Bryozoa*. Dr. M. W. Twitchell has determined the following species of *Echinoids* from the Eocene of Craven County:

Scutella alta Conrad.
Echinocyamus parvus Emmons.
Cidaris carolinensis Emmons.
Cidaris mitchelli Emmons.

He believes the fossils indicate the upper Claibornian age of the strata.

Thus far very little work has been done on the Trent fauna, but in the near future it is planned to make a detailed study of these interesting forms.

With the exception of a few outliers along Contentnea Creek and in Harnett and Moore counties, outcrops of the Trent formation are confined to the area lying between the Neuse and Cape Fear rivers and extending from New Bern westward to Raleigh. In Jones County it attains its greatest development. It outcrops as continuous strata for many miles along the Trent River and its tributaries, and apparently underlies the entire western part of the county, though concealed from view except in the stream valleys. In Craven County it outcrops in several places along the Neuse River west of New Bern and along the Trent River between New Bern and Polloksville. It probably underlies the greater part of that portion of the country lying south of the Neuse River and west of New Bern. In Pitt and Greene counties it is reported to occur along Contentnea Creek in the vicinity of Snow Hill. In Lenoir County it outcrops along the Neuse River a few miles below Kinston, and it is believed to underlie the Miocene and Pleistocene of the southern part of the county, though no exposures are known. It is exposed in several places along the New River in and near Jacksonville.

In Wayne County the Trent formation is discontinuous, but outcrops in several places. In the Sarpony Hills, on the south side of the Neuse

River southeast of Goldsboro, limestones belonging to this formation have been quarried and burned for lime. West of Goldsboro, near the junction of Falling Creek and the Neuse River, similar limestones occupy a few small depressions in the crystalline rocks. In the southern part of the county strata belonging to this formation have been exposed in marl pits in the vicinity of Mount Olive.

Eocene strata referred to the Trent formation are represented in the northern and western portions of Duplin County, especially near Faison. The somewhat calcareous sand exposed in the Natural Well near Magnolia has been thought by some to belong to the same horizon, though there seems to be no sufficient reason for such correlation.

In Sampson County this formation has furnished limestone used in the manufacture of lime. It occurs in isolated areas in the southeastern portion of the county along Six Runs River. In Bladen and Columbus counties there are a few doubtful exposures of Trent strata along the Cape Fear River.

The outliers of this formation in the Piedmont district indicate a much wider distribution at an earlier period. They are found in small patches near Auburn in Wake County, a few miles northeast of Spout Springs in Harnett County, and in the southeast corner of Moore County. In all probability these isolated areas were at one time connected with each other and also with the main mass of the same formation lying farther east. We have evidence to show that part of the missing Eocene strata were removed before Miocene time, as the Miocene strata in some places rest directly upon the Cretaceous, while similar evidence in the Wilmington region, where the Castle Hayne and Peedee formations are in contact, indicate that the Trent was probably extensively eroded before the deposition of the later Eocene. Of course it is possible that the Trent was never deposited there, though that seems unlikely, since there is no evidence of the existence of any land barrier shutting out the ocean waters such as would have existed if the coast region had been a land area during Trent time. Instead, the character of the fossils and the lithological materials constituting the formation indicate the place of deposition to have been the open ocean.

In South Carolina there are Eocene strata which are similar lithologically and perhaps faunally, though this has not yet been determined, to the Trent deposits. It seems probable that these areas were likewise continuous at one time, though now separated by a considerable distance. It seems less probable, however, that the Trent formation was ever continuous with any of the Eocene strata of Virginia, as they are so dissimilar both in faunal and lithologic characters. It is not unlikely that the Coastal Plain region of northern North Carolina and southern

Virginia was a land area during the deposition of the Trent, and the formation did not extend much farther north than its present position.

Structure.—As is true of all the strata of the Coastal Plain, the structure of the Trent formation is extremely simple. The beds in some places are practically horizontal, but, in general, dip toward the ocean at the rate of about 3 to 5 feet per mile.

Detailed Sections.

Spring Garden Landing, Neuse River.—A hard white Eocene limestone rises in the low river bank about 3½ feet above the level of the water in the river. The limestone contains many fossil casts, the shell substance is entirely gone, and the cavities are usually filled with calcite crystals. In places the cavities have not been filled. This rock has been used for buhrstones.

The fossils present, though numerous, are not varied.

Above the rock occurs thinly laminated drab clay and gray sand of Pleistocene age with an average thickness of about 10 feet.

In the river bank the Eocene is well exposed.

SECTION ROCK LANDING, NEUSE RIVER.

	Feet.
Pleistocene:	
Yellowish-brown loam and sand with a few small pebbles, principally concealed by vegetation	3-8
Eocene (Trent):	
Hard, firmly indurated white limestone filled with casts and moulds of fossils, the shell substance having been largely removed, leaving cavities which, in some places, have been filled with calcite crystals. Grades into next member	4½
Less firmly indurated limestone containing pockets of brownish-gray sand, many hard nodules of brown sandstone bored by *Teredo*, and fossils, many of which preserve the shell structure, especially *Pecten*, *Ostrea*, and *Echinoids*. Grades into members below and above	1
Loose brownish to yellowish-gray quartz sand with many small black grains, principally magnetite; contains no fossils. Exposed to water's edge	5

The indurated layer in the above section is the one exposed at Spring Garden Landing, and it also outcrops along many small streams south and southeast of Rock Landing. About 2 miles south of Rock Landing it outcrops as a continuous ledge about 4 feet in thickness at the head of a small stream for a distance of about ½ mile. Many excellent springs issue from beneath it.

Biddle Landing, Neuse River.—Here there is a thickness of about 20 feet of Eocene sandy limestone exposed. In places the gray calcareous

sand filled with tiny shell fragments is uncemented, but, in most places, it is cemented and in certain places very firmly. The shell fragments cannot be distinguished in some of the layers, as the lime has been removed and reprecipitated. Sharks' teeth, *Pectens, Echinoid* spines, *Bryozoa, Scutella,* and *Ostrea* were found. *Bryozoa* and *Ostrea* are especially abundant. The material bears some resemblance to the Eocene at Wilmington, though it is at present referred provisionally to the Trent formation.

The fragmental shell rock shows cross-bedding, with the laminæ dipping rather steeply downstream.

SECTION RIGHT BANK OF NEUSE RIVER, 17½ MILES BELOW KINSTON.

	Feet.	Inches.
Pleistocene:		
Pleistocene sand and loam not well exposed	8-12	
Eocene (Trent):		
Black laminated clay, weathering white on exposure	7-12	
Pebble band consisting of black pebbles and containing fragments of sharks' teeth, *Belemnitella, Gryphea,* and *Exogyra,* which have been derived from the Cretaceous	...	8
Cretaceous (Peedee):		
Glauconitic sandy clay containing many fossils exposed to within 3 feet of water, where it is hidden from view	11	

The unconformity between the Eocene and the Cretaceous is well shown in this locality. At one place the basal stratum of the Eocene is 14 feet above water. It inclines to the north to the water's edge, then rises and remains about 7 feet above water for a considerable distance.

SECTION NEUSE RIVER, 6½ MILES BELOW KINSTON.

	Feet.	Inches.
Pleistocene:		
Disturbed Pleistocene clay	2½-3	
Drab shaly clay, no fossils	1½	
Eocene (Trent):		
Band of black water-worn pebbles, some of the pebbles fossiliferous, some crystalline, in matrix of gray sand	...	8
Cretaceous (Peedee):		
Micaceous, greenish-black argillaceous sand	7	

The Eocene material contains some concretions of very hard cemented quartz sand, both black and white, containing some small shells. The black pebbles seem to be phosphatic. Among them were recognized a few greatly worn sharks' teeth and small pieces of bone.

Broadhursts Bridge, Neuse River, 82 1-4 Miles Above New Bern.—Eocene limestone appears on right bank of stream on both sides of the bridge. It can be seen rising about 4 feet above the water in one place.

Echinoids, sharks' teeth, etc., are present. A few rods downstream the marine Cretaceous appears, while ¾ mile above the bluff, where the other Eocene section described below is exposed, the Cretaceous also appears. This shows that the Eocene occupies a basin in the Cretaceous.

SECTION JUST ABOVE 83 MILEPOST, NEUSE RIVER.

	FEET.
Pleistocene:	
Talus-covered slope	25-35
Eocene (Trent):	
White to greenish-white soft limestone containing some fossil casts. *Pecten* is common. Limestone contains some glauconite	40
Greenish-blue, hard, argillaceous limestone, with echinoid spines, portions of echinoid tests, etc.	6

The limestone has been burned for lime.

On the farm of D. L. Flowers, about 3 miles directly west of Mount Olive, there is a marl pit from which marl is taken for fertilizing purposes. The marl consists principally of a rotten limestone containing many fragments of shells. Casts of bivalves, fragments of Echinoderm tests and spines were observed. Lithologically, the material resembles the other Eocene of the region. The pits are located near a small branch. A few feet of surface clays are stripped off and pits are dug to a depth of about 25 feet in the marl. The material is very dry, no water interfering with the digging. After exposure to the air the marl soon crumbles to powder.

One pit penetrated the marl at 25 feet. One pit 23 feet in depth did not pass through it. Near the upper surface the marl is of a light yellowish color, but deeper it is of a very pale greenish color.

About 100 yards to the west of the pits, on the other side of the branch, a well was drilled to a depth of 151 feet. It is perhaps 20 feet below general level of the surrounding country. The water rises near enough to the surface to pump with a pitcher pump.

SECTION 3 MILES WEST OF MOUNT OLIVE.

	FEET.
Pleistocene:	
Sand and clay	0- 12
Eocene (Trent):	
Marl similar to that in marl pit	12-150

The water comes from just below the marl, from material containing small leaves resembling cypress leaves, probably of Cretaceous age.

About 1 mile west of Mount Olive marl is reported which contains an abundance of sharks' teeth.

Marl is also reported to the northwest of Mount Olive 1 mile, and to the east 2 miles.

Marl has been dug for fertilizing purposes about 3 miles to the southeast of Mount Olive.

Junction of Falling Creek and Neuse River.—At this place Eocene marl has been dug within the last few years. It consists of calcareous sand, rather firmly cemented in certain places and containing many fossils, particularly *Bryozoans, Echinoids,* bones, and sharks' teeth. The marl occupies a depression in the crystalline rocks, which are exposed a few rods away. This is the locality referred to by Olmsted in 1827. Similar marl is reported from a few other localities in the immediate vicinity.

Rock Spring, 4 Miles Above New Bern on Right Bank of Trent River. Shell rock of Eocene age appears in bank about 3 feet above high tide. It contains an abundance of casts and impressions of fossils. It is overlain by yellowish-colored Pleistocene sand containing small pebbles. At the base there is some glauconite, presumably derived from the Cretaceous.

White Rock Landing, Left Bank of Trent River, About 12-13 Miles Above New Bern.—The Eocene limestone appears here and rises about 15 feet above the water. Casts of fossils are numerous. The Eocene is overlain by about 15 feet of Pleistocene strata consisting principally of yellowish-brown, loamy clay, containing some small pebbles. The same stratum of Eocene rock is exposed at many other places along Trent River in the same vicinity.

SECTION NORTH END OF A. C. L. BRIDGE, POLLOKSVILLE, N. C., NEW BERN QUADRANGLE.

	Feet.
Pleistocene:	
Several feet of sand or sandy loam poorly exposed	3-10
Eocene:	
Massive beds of *Ostrea georgiana* with yellow sand matrix. No other form was seen, except possibly another species of oyster and a few barnacles attached to oysters. The largest oyster measured about 12½ inches in length. To water's edge, Trent River	15

The exact thickness of the shell bed is rendered somewhat uncertain by the fact that some mixing has taken place in digging the cut, and it has been further obscured by growth of weeds, grass, etc. The oysters are long, thick, massive, and heavy. They are very rotten and crumble so easily that it is almost impossible to secure perfect specimens.

The same bed of oysters is exposed in the cut about 100 yards south of the Polloksville depot. It differs from the preceding, however, in that portions of the upper part are indurated. The indurated portions are irregular in form, not in layers, and in places are several feet in

A.—Exposure of *Ostrea georgiana* bed of the Trent formation, Trent River, Pollocksville, N. C.

B.—Walkers Bluff, Cape Fear River, showing the Waccamaw formation overlying the Black Creek formation.

thickness. They consist of hard, more or less siliceous fossiliferous limestone, similar lithologically to portions of the Eocene rock at Wilmington.

In the upper portion of this bed, especially in the indurated material, several other forms occur besides the *Ostrea* and *Balanus*, with which they are closely associated. Some of these found are: *Echinoderms*, *Cardium*, encrusting Bryozoa, one small specimen of branching *Bryozoa*, sharks' teeth, several *Pelecypods* and *Gastropods*.

TRENT RIVER, LEFT BANK; ½ MILE ABOVE POLLOKSVILLE, AND JUST BELOW THE NORFOLK SOUTHERN RAILROAD BRIDGE. FARM OF DR. HUGHES.

The same bed of oysters exposed at Polloksville is exposed in old marl pits. In one fresh cutting the marl rises 10 feet above water's edge. The matrix is a greenish-gray sand, more or less mottled with yellow. Nothing was observed but large oysters and barnacles. There is also an old marl pit just above the bridge.

One Mile East of Olivers.—Along the roadside west of Mill Run, 1 mile east of Olivers, there is an exposure of about 4½ feet of Eocene. It consists of a medium coarse, buff to yellow sand, containing irregular masses of limestone varying in diameter from 1 to 14 inches. The limestone contains fossil impressions. In the loose sand and also in the limestone masses are numerous small sharks' teeth.

One Mile Southwest of Olivers.—On tributary branches of Mill Run, about 1½ miles southwest of Olivers, Mr. John C. Parker has dug Eocene marl for fertilizing purposes. The marl consists almost entirely of *Ostrea georgiana*, some specimens of which were 20 inches long and are usually found in an upright position in the matrix of sand. The marl bed lies about 4 feet from the surface and is about 6 feet thick. He has used it extensively on his fields and has burned some of the shells for lime. Farther up the creek the marl is said to consist of disintegrated fine shells and sand. It is not exposed.

SECTION WHITE BANK LANDING, TRENT RIVER.

	FEET.
Pleistocene:	
Yellowish-brown, sandy loam, passing downward into very loose, fine, mealy, white to buff, stratified sand, in which are many lenses of small quartz pebbles	20
Eocene (Trent):	
Gray to greenish-gray, fine marly sand, containing quantities of *Bryozoa* of various kinds and some *Pectens*, *Ostrea*, and *Echinoids*. One good specimen of *Scutella* was found. The most common *Bryozoa* are colonial forms, in which the mass looks, in shape and size, much like an *Echinoid*. To water's edge	8

A short distance above the bridge the Eocene limestone is well exposed. Section is as follows:

SECTION TRENT RIVER AT TRENTON.

	Feet.
Pleistocene:	
Sand and loam, with some gravel largely concealed by vegetation.	15-20
Miocene (Yorktown?):	
Fine, mealy, buff to orange sand	3-4
Eocene (Trent):	
Limestone or marly sand. When dry it becomes hard and firm, though not compact, but when wet it can easily be dug with the hammer. Contains *Bryozoa, Echinoids, Pecten, Ostrea,* and casts of numbers of other *Pelecypods,* and also *Gastropods.* Exposed to water	5

This limestone forms almost continuous outcrops for a distance of several miles along the Trent River in the vicinity of Trenton.

An artesian well on the property of T. A. Windley, in Trenton and on the Trent River bank, which is about 25 feet high, showed the following section:

SECTION ON PROPERTY OF T. A. WINDLEY.

	Feet.
Pleistocene:	
Loam and sand	25
Eocene (Trent):	
Soft limestone, somewhat porous	5
Below the above layer, sandy marl with occasional pieces of rock were encountered to bottom of well, which is in hard rock	68

It seems that all but the upper 25 feet is Eocene, which makes it 73 feet thick.

Beaver Creek, 2 Miles Northwest of Wilcox Bridge, on Trent River.—At this place a fine Eocene sand has been dug, evidently for building purposes. It is light greenish-gray in color. In the bank it is hard and compact, but a pile of it near the pit is very loose and soft. The sand contains numerous fossils, though these are not readily observed except on the weathered surface of the pile of sand. *Bryozoa* are most abundant, though a *Foraminifera* (*Frondicularia?*), sharks' teeth, fragments of bones, *Ostrea,* Echinoid spines and fragment of an Echinoid test were also found. Similar sand is exposed along the east side of Heath Mill Run, 1-3 mile east of Foys Station.

Jacksonville, N. C., East End of Bridge over New River.—A hard fossiliferous Eocene limestone outcrops at this point, resting about 8 feet above high-water level.

Two and One-Half Miles South of Richland.—Where the Richland-Jacksonville road crosses a small branch a hard white limestone is

exposed in the roadbed a few feet above the level of the water in the stream. Lithologically, it resembles the limestone exposed at many places along the Trent River.

Rock of a similar character is exposed where the same road crosses the New River, about 1 mile south of Richland.

Two Miles Northeast of Jacksonville.—At this point marl has been dug for fertilizing purposes. It consists of a rather rotten fossiliferous limestone which contains some *Echinoids*.

Three Miles Northeast of Spout Springs, Harnett County, Near Reedy Swamp, Head of Jumping Run.—The Trent formation occurs at this point, but is poorly exposed. It consists of a light colored, somewhat chalky limestone which is somewhat siliceous in places. It is soft when first removed, but hardens on exposure. It contains some fossil *Bryozoa* and *Echinoderms*. The outcrop is near the top of the hill and probably caps it. A short distance away a similar hill is capped with a ferruginous sandstone, which probably contains the same stratum of Trent limestone, though it is not exposed. Similar material is also reported west of Spout Springs.

CASTLE HAYNE LIMESTONE.

Name.—Up to the present time no attempt has been made to differentiate the Eocene strata of North Carolina, and therefore the name Castle Hayne is proposed for those beds that constitute the upper Eocene horizon of the State. The name is especially appropriate, because the exposures of this formation in the vicinity of the town of Castle Hayne are typical of the formation, and also because the section exposed at this locality has been described in the literature at several different times.

Definition.—The Castle Hayne formation constitutes the youngest Eocene strata of North Carolina and consists of calcareous marls, fossiliferous limestones, and conglomerates that are extensively developed in Onslow, Pender, and New Hanover counties. The deposits rest upon older strata of Cretaceous or Eocene age and are in turn succeeded and overlain by deposits belonging to the Miocene, Pliocene, and Pleistocene.

The Castle Hayne formation, so far as observations of outcrops can determine, everywhere rests unconformably upon marine Cretaceous strata. The fossils which it contains indicate a younger formation than the Trent, yet the two have not been observed in contact. It is probable that the two are in contact in the region lying to the southeast of Wilmington, as revealed by well records. They must be unconformable, as the evidence of an erosion period between the deposition of the two

formations has been given on an earlier page. At numerous places along the Northeast Cape Fear River the Castle Hayne can be seen resting directly upon the Peedee, while it is in turn overlain, unconformably, by the Miocene or some member of the Pleistocene.

In the city rock quarry at Wilmington small patches of Miocene shell marl occupy pockets of solution in the surface of the eroded Castle Hayne limestone. Thus we have evidence of an uplift of the region forming land and resulting in a period of erosion preceding and following the deposition of the strata constituting the Castle Hayne formation, and causing it to be unconformable with both the underlying and overlying beds.

The Castle Hayne formation, as shown in the detailed sections given on a later page, contains several different kinds of materials. The most common constituent, however, is fossiliferous limestone of varying hardness and purity. At Rocky Point on the Northeast Cape Fear River this limestone is well developed and has given the name to the locality because of its outcropping at that place. It has been quarried there for constructional purposes. At the city rock quarry just north of Wilmington the limestone is firmly cemented in certain parts, while it consists of a loose, calcareous marl in other portions. It contains many holes of solution and pockets of glauconitic sand and clay that have been deposited in solution cavities. The limestone in most places contains many fossils, particularly *Bryozoa* and *Echinodermata*. In certain places the bulk of the rock consists of the remains of *Bryozoa*.

At the base of the formation there is a layer of pebbles and cobbles that is well developed in the rock quarries at Castle Hayne and along Smith Creek. The pebbles are black in color and are rich in calcium phosphate. Associated with them are many water-worn Cretaceous fossils, principally in the form of casts. Sharks' teeth are especially abundant in this layer in the Castle Hayne rock quarry. This pebble layer is firmly cemented in certain places to form a hard conglomerate.

Thickness.—The Castle Hayne formation does not attain any considerable thickness at any place where it outcrops. Where it has been penetrated by well borings it has not been possible to determine where the line separating the Castle Hayne and Trent formations comes. So far as we know, the deposits of the former are not so thick as the latter, which we know to be over 70 feet thick and probably somewhat more than 100 feet. If, therefore, we refer 100 feet of the Eocene materials penetrated in the wells at Greenville Sound and Masonboro Sound to the Trent, there remains only 30 to 35 feet of Castle Hayne materials. Though the formation may be somewhat thicker elsewhere, it seems probable that it nowhere exceeds 50 feet.

The fossils of the Castle Hayne formation have, as yet, received little attention apart from the slight investigations made by several persons to show the commingling of Cretaceous and Eocene forms in the basal beds at Wilmington and Castle Hayne. It is now generally believed that the Cretaceous fossils have been derived from the underlying Peedee beds, though, in some cases, they show no evidence of having been water-worn. The *Mollusca* constitute a considerable portion of the Castle Hayne, though of much less importance relatively than in the succeeding formations of the Miocene. The *Bryozoa* are represented by quantities of specimens and numerous species in almost every stratum of the formation, while the *Echinodermata* are abundant. Perfectly preserved tests of *Echinoids* are common in the limestones at both Wilmington and Castle Hayne, while loose spines are found associated with the Bryozoan remains. The great quantity of specimens of the *Brachiopod, Terebratula wilmingtonensis,* is another interesting feature of the fauna of this formation. This species is peculiar in that the different specimens show such a wide range of variation.

The following fossils have been obtained from the city rock quarry at Wilmington. Dr. T. Wayland Vaughan has determined the corals, recognizing the following forms:

ANTHOZOA:
Flabellum sp.
Madracis sp.
Endopachys maclurei (Lea).
Balanophyllia sp.

Dr. M. W. Twitchell has determined the Echinoids. He recognizes—

ECHINOIDEA:
Cassidulus (Pygorhynchus) lyelli Conrad.
Cassidulus (*Rhynchopygus*) n. sp.
Echinolampas appendiculatus Emmons.
Hemipatagus sp.
Scutella lyelli Conrad.
Clypeaster (?) sp. (may be young Scutella).

Miss Julia A. Gardner has determined the following bryozoans, brachiopods, and mollusks:

BRYOZOA:
Lunulites distans Lonsdale.
BRACHIOPODA:
Rhynchonella salpinx Dall.
Terebratulina lachryma Morton.
Terebratula wilmingtonensis Lyell and Sowerby.

GASTROPODA:
Bulla (?) sp.
Calyptrea (?) *trochiformis* Lamarck.
Cassis (?) sp.
Cerithiopsis sp.
Conus gyratus Conrad.
Conus sp.

Crucibulum sp.
Cypraea sp.
Leviformis (?) *trabeatus* Conrad.
Marginella sp.
Melongena (?) sp.
Mitra sp. cf. undesc. sp. from Ocala, Fla.
Mitra (?) sp.
Oliva (?) sp.
Puncturella sp.
Scala octolineata Conrad.
Scala sp.
Scaphella cf. ocalana Dall.
Serpulorbis (?) sp.
Siliquaria (?) *vitis* Conrad.
Strombus sp.
Triforis (?) sp.
Turbinella sp.
Siliquaria (?) *vitis* Conrad.
Volutilithes sp.
Xenophora conchliophora Born.

PELECYPODA:
Arca sp.
Cardium sp.
Crassatellites altus Conrad.
Crassatellites sp.
Exogyra costata Morton.
Isocardia sp.
Modiolus sp.
Ostrea sp.
Panopea sp.
Pholadomya (?) *claibornensis* Aldrich.
Pholadomya sp. cf. undes. sp. from Cretaceous of Wilmington.
Pecten membrannosus Morton.
Pecten scintillatus Conrad.
Plicatula filamentosa Conrad.
Spondylus dumosus Conrad.
Tagelus (?) sp.
Tellina (?) sp.
Venericardia sp.
Veniella sp.

CEPHALOPODA:
Nautilus sp.
Aturia sp.

Sufficient data have not been obtained to determine definitely the limits of the Castle Hayne formation. The type section is exposed in the quarries near Castle Hayne, while the section exposed in the quarries on Smith Creek just north of Wilmington is similar. The Eocene strata that outcrop at frequent intervals along the Northeast Cape Fear River as far as Chinquapin Landing, 79 miles above Wilmington, seem to belong to the same formation as far as their lithologic character is concerned. At Black Rock Landing on the Cape Fear River, 37 miles above Wilmington, the formation again outcrops. In the vicinity of Elpaso, Brunswick County, it is exposed in several places, while it has been penetrated by the drill in several deep wells east and southeast of Wilmington.

The Castle Hayne formation mainly occupies depressions in the surface of the Cretaceous and occurs in isolated areas usually of rather small extent. Under these conditions the structure is not readily obtained. So far as known, the strata seem to be practically horizontal or with a very slight dip in the direction of the ocean similar to most of the other formations of the Coastal Plain. There is no evidence of the formation having suffered deformation, though it has undoubtedly been elevated and depressed several different times since its formation.

Detailed Sections.

Along Northeast Cape Fear River Eocene strata of the Castle Hayne formation are exposed at several places, but they are always thin and rest unconformably upon the Cretaceous, which is exposed in many of the sections. At Chinquapin Landing, 79 miles above Wilmington, the limestone rock which contains many *Bryozoa,* is exposed at low water. Lithologically, it is similar to the Eocene strata exposed at Wilmington. Just below Chinquapin Landing a calcareous, slightly glauconitic, fossiliferous sandstone rises about 2 feet above the water and is similar in appearance to the rock at Chinquapin Landing.

SECTION DEEP BOTTOM BRIDGE, LEFT BANK NORTHEAST CAPE FEAR RIVER, JUST BELOW 75 MILEPOST.

	Feet.
Pleistocene:	
Light colored loose sand	10-12
Eocene (Castle Hayne) (?):	
Drab laminated clay with partings of sand	2
Light drab laminated clay with layers of gray sand	3½
Dark gray, somewhat glauconitic sand, rather coarse in places, very compact toward the base. Contains a few poorly preserved specimens of *Ostrea*	9

SECTION ONE-EIGHTH MILE BELOW DEEP BOTTOM BRIDGE, LEFT BANK NORTHEAST CAPE FEAR RIVER.

	Feet.
Pleistocene:	
Yellow loam, grading downward into light drab sandy clay, mottled with red	10
Eocene (Castle Hayne) (?):	
Rusty brown sandy clay, containing poorly preserved fossil casts	½-1
Stratified drab sand and clay mottled with pink	3½
Loose gray sand, stained with iron in places	10
Loose gray sand, containing thin laminæ of drab clay	4
Loose, coarse yellow sand with some thin laminæ of drab clay at base	4
Dark-green glauconitic sand	1
Dark drab compact plastic clay	5
Pebble bands composed of black fossiliferous pebbles in a matrix of dark-colored argillaceous sand. Contains occasional pieces of brown lignite and numerous sharks' teeth, some of which are water-worn	0-½
Cretaceous (Peedee):	
Dark green, glauconitic, micaceous sand, containing pebbles	1½

In the two preceding sections the upper strata of the material referred to the Eocene are probably correctly correlated, though it is possible that certain of the beds should be referred to the Miocene.

SECTION AT "THE BLUFFS" ON NORTHEAST CAPE FEAR RIVER, 6 MILES SOUTHEAST OF BURGAW, 41½ MILES ABOVE WILMINGTON.

	Feet.
Pleistocene:	
Loose white to yellow sand, containing a few layers of drab clay.	
Eocene (Castle Hayne):	
Loose light greenish-gray micaceous sand, containing considerable glauconite at base, with a few fragments of branching Bryozoan fossils	9

Marl is reported to occur a few miles north of this locality.

At Rocky Point the Eocene is well exposed, a hard layer of limestone which is there developed having given the name to the locality. It seems probable that the Eocene is developed as a continuous bed all along Northeast Cape Fear River, though in places it has probably been entirely worn away by pre-Pleistocene erosion.

About 30⅛ miles above Wilmington and 3¼ miles above Castle Hayne bridge, on the left bank of Northeast Cape Fear River, rotten fossiliferous Eocene rock, similar to certain layers at the Castle Hayne rock quarries, rises 7 feet or 8 feet above water's edge.

SECTION AT ROCK QUARRY, CASTLE HAYNE.

	Feet.
Pleistocene:	
Loose, dry, light-gray sand, fine in texture	1-2
Sand, varying in color, gray and yellow, and varying in texture, coarse to fine	0-2
Streak of clean, pure, white sand, fine grained, and varying in thickness, there being some pockets or lenses as much as 2 feet in thickness	0-2
Mottled yellow and pink argillaceous sand, rather hard and resistant when dried in the sun	2-3
Streak of dark sand, which may owe its color to vegetable matter.	0-1
Greenish-gray sandy clay, mottled with yellow and pink in places. The brown color is probably due to decomposition of glauconite, and oxidation of the iron. There are also present white streaks, probably lime. Both the lime and the glauconite are derived from the underlying Eocene. The band occurs along the line of unconformity	0-1
Irregular contact.	
Eocene (Castle Hayne):	
Fossiliferous Eocene limestone, very much decomposed. Cavities have been formed in this limestone by the solution of lime by water. In places the cavities have been partially refilled by a deposit of glauconite sand brought in by running water. Contains great quantities of sharks' teeth	0-8
Solid fossiliferous limestone containing many perfect Echinoid fossils	1-2
Conglomerate, consisting of dark green to black phosphate pebbles up to 3 inches in diameter, also sandstones and quartz pebbles and sand grains, all cemented with lime. This layer contains many Cretaceous fossils mixed with characteristic Eocene species	1

A.—Exposure of the Castle Hayne formation in the rock quarry near Castle Hayne, New Hanover County, N. C.

B.—Exposure of Castle Hayne formation in city rock quarry near Wilmington, N. C.

At one place in the quarry a strong spring of water issues from a cavity in the conglomerate rock. A striking feature of the quarry section is the manner in which the later materials have been deposited upon the uneven surface of the Eocene, each layer being thicker above the Eocene depression, and thinner above the Eocene elevations. In this manner the surface of each successive layer becomes more nearly level. The present surface is quite level.

The decayed Eocene limestone and the solid limestone contain some grains of glauconite.

Cretaceous strata have been exposed beneath the Eocene conglomerate, though not visible at the present time.

This locality has received considerable attention by several investigators in the past on account of the mingling of the Cretaceous and Eocene forms in the basal layers. The Cretaceous forms, in the main, show evidence of being water-worn, though some are in almost perfect condition and seem to have been redeposited without having undergone much change.

The rock from this quarry has been extensively used on the roads about Wilmington and makes a very hard, firm roadbed.

SECTION AT WILMINGTON, CITY ROCK QUARRY, LOCATED ON SMITH CREEK.

	Feet.	Inches.
Pleistocene:		
Sandy soil	4-8	
Miocene:		
Thin, isolated patches of Miocene shell marl in depressions in irregular eroded surface of the Eocene. The maximum thickness observed		10
Eocene (Castle Hayne):		
Calcareous marl full of holes of solution which are filled with clay. In some places the marl is quite firmly cemented	6-8	
Fragmental shell rock, few entire shells found. Upper part cemented to form hard rock; lower, loose	3	6
Pebble layer with water-worn black pebbles firmly cemented. Contains many sharks' teeth	3-4	

The following section shows the character of the materials passed through in sinking the well of the ice company owned by W. E. Worth & Co.

SECTION AT WILMINGTON, N. C., WELL OF ICE COMPANY, OWNED BY W. E. WORTH & CO.

	Feet.
Pleistocene:	
Sand	20
Miocene (Yorktown?):	
Not recognized.	

Eocene (Castle Hayne and Trent):	FEET.
Calcareous marl interstratified with strata of shells	65
Hard shell rock	4
Shell marl, containing some water	2
Shell rock	6
Shell rock with cavities, water-bearing	4

SECTION AT BLACK ROCK LANDING, RIGHT BANK OF CAPE FEAR RIVER, 37 MILES ABOVE WILMINGTON.

Pleistocene:	FEET.
Mottled red and orange-yellow sand, passing downward into a brownish-yellow sandy clay	24
Layer of fine quartz pebbles poorly exposed	½-1
Eocene (Castle Hayne):	
White sand containing considerable calcareous material and inclosing some fragile fossils. At the base are some phosphatic nodules, a few of which measure over 6 inches in diameter	4
Cretaceous:	
Dark blue to black micaceous sandy clay	8

About 1 mile south of Elpaso postoffice, Brunswick County, a solid Eocene limestone rock, with many casts of shells, principally *Cardium* and a few *Gastropods,* outcrops along a small branch to the west of the road. In places the rock is decidedly arenaceous.

The farm of George H. Bellamy, about 2½ miles south of Elpaso postoffice, is in part underlaid by limestone rock. One poor exposure was seen at a spring a few hundred yards from his residence.

In former years the limestone was used as a fertilizer, and many small pieces of a rather rotten fossiliferous limestone rock may be seen scattered about in nearly all his fields. A few fossils were obtained from these pieces which seem to belong to the same species as those occurring at the rock quarries at Wilmington and Castle Hayne. It is evident, therefore, that the rock underlying Mr. Bellamy's land represents the same horizon as those localities.

Lithologically, the pieces of rock picked up in the fields resemble the soft rotten rock exposed in the Wilmington rock quarries, and the outcrop seen at the spring is the same as the solid white limestone overlying the phosphate conglomerate at that place.

SECTION OF WELL No. 2, WINTER PARK GARDEN, 3 MILES EAST OF WILMINGTON.

Pleistocene:	FEET.
1. White, coarse, gravelly quartz sand. One pebble an inch long, probably a partially decomposed igneous rock	32- 44
2. Very coarse, gravelly quartz sand	44- 50

	Feet.
Miocene (Yorktown):	
3. Shell marl in a matrix of gravel and sand. The following forms, probably all Miocene, were recognized: *Glycymeris aratus* Conrad, *Venericardia granulata*, spines and portions of tests of *Echinoderms*, *Leda* (?), several *Gastropods* and several *Pelecypods*	50- 54
Eocene (Castle Hayne and Trent):	
4. White, medium to coarse-grained, loose sand with numerous fragments of Pelecypod shells and some *Bryozoans*. The former are probably Miocene fallen down from above, while the latter are Eocene	54- 57
5. Driller's description: hard rock. Consists largely of fragments of *Bryozoa* and other fossils with much sand, and fragments of gray, sandy, limestone rock	57- 60
6. Similar to No. 5, but contains a larger percentage of lime in form of fossil fragments and a correspondingly less amount of sand	60- 75
7. Clean, loose, coarse, gravelly sand, with a few *Bryozoan* remains	75- 78
8. Driller's description: hard rock. White sandy limestone with numerous *Bryozoan* remains. Many of the rock fragments tinged with green, probably due to phosphate.	78- 83
Marine Cretaceous:	
9. Dark green, calcareous, finely arenaceous and micaceous, and slightly glauconitic clay. Assigned to marine Cretaceous because of its lithologic resemblance to material of that age in this region	83- 88
Total depth	140

SECTION OF WELL AT GREENVILLE SOUND, 6 MILES SOUTHEAST OF WILMINGTON.

Pleistocene (?):	
No samples	1- 35
Eocene (Castle Hayne and Trent):	
1. Gray, medium to coarse-grained, calcareous sand (described as rock by driller and probably indurated), with numerous fragments of bivalve shells and branching and encrusting *Bryozoans*. (This sample may be a mixture of Eocene and Miocene)	35- 38
2. Driller's description: soft rock and sand. White arenaceous limestone rock, consisting largely of fragments of *Bryozoans*, branching and encrusting forms	38- 50
3. Similar to sample No. 2, but containing a much larger percentage of sand, in coarse grains, and, in addition to *Bryozoa*, contains bivalve fragments, *Echinoderm* fragments, and one small *Gastropod*	50- 53
4-6. Rather dark gray, very fine-grained, calcareous and slightly glauconitic sand, with fragments of *Bryozoans* and *Pelecypods*. Lithologically resembles Cretaceous	53- 100

		Feet.
7.	Driller's description: sand and thin layer of rock similar to Nos. 4-6, but contains a larger percentage of lime in form of fossil fragments and is lighter in color	100- 120
8-9.	Driller's description: rock and sand, similar to No. 7, but a still larger percentage of lime	120- 150
10.	Driller's description: sand and thin layers of rock. White calcareous sand and small sand-rock fragments, containing small *Bryozoans*	150- 170
	Total depth	170

SECTION OF WELL AT MASONBORO SOUND, 7 OR 8 MILES SOUTHEAST OF WILMINGTON.

		Feet.
Pleistocene:		
1.	Medium-grained, clean white quartz sand	0- 15
Eocene (Castle Hayne and Trent):		
2-3.	Coarse, clean white quartz sand, with some rose-colored grains and occasional white grains of calcium carbonate.	25- 45
4.	Very coarse, clean quartz sand, with some grains of rose quartz, numerous coarse grains of glauconite, occasional fragments of shells and fragments of two species of *Bryozoans*	45- 58
5.	Soft white limestone rock, consisting principally of fragments of *Bryozoans*. Very pure calcium carbonate	58- 78
6.	Medium hard white limestone rock, consisting largely of Bryozoan remains, branching and encrusting forms	78- 85
7.	Soft sandy white limestone rock, with a few imperfect *Bryozoan* remains	85- 95
8.	Hard white limestone rock, slightly sandy, containing *Bryozoans*, both encrusting and branching forms, in considerable numbers, and one small specimen of *Gastropod*	95- 105
9.	Loose, fine-grained, calcareous, slightly micaceous and slightly glauconitic gray sand	105- 125
10.	Loose, fine-grained, calcareous, slightly micaceous sand, a little darker than the preceding. A few branching *Bryozoans*	125- 135
11.	Same as sample No. 10, but darker gray	135- 155
Cretaceous (?):		
12.	Coarse, gray, calcareous sand and rock (presumably in alternate layers), containing many fragments of shells, probably for the most part *Ostrea* and a few *Bryozoans*, which may have fallen down from above. Lithologically resembles Cretaceous	155- 165
	Total depth	187 (?)

SECTION OF WELL AT FORT CASWELL NEAR THE MOUTH OF CAPE FEAR RIVER, N. C., FROM SAMPLES FURNISHED BY THE OFFICER IN CHARGE.

		Feet.
Pleistocene:		
1.	Loose beach sand, with small shell fragments	0- 30
2-3.	Gray, calcareous, sandy clay, with well-preserved Pleistocene fossils, *Barnea*, *Crepidula*, *Nassa*, etc	30- 45

		Feet.
4-6.	Loose calcareous sand, with numerous shell fragments, and in sample No. 6 large pieces of Pleistocene fossils as follows: *Cardium fondo, Ostrea, Scutella, Crepidula;* also, in sample No. 6, pieces of calcareous sand-rock, fragments of peat, iron crusts, and one fragment of crystalline rock, probably granite	45- 78
Eocene (Castle Hayne and Trent):		
7-8.	Yellow, medium-grained, calcareous sand, with a few scattered grains of glauconite and many fragments of shells, especially branching *Bryozoans*	78- 102
9.	Pale yellow, fine-grained, calcareous, slightly glauconitic sand	102- 109
10.	Like samples 7 and 8, but contains numerous small pieces of chalk-like rock	109-110¾
11.	Pure white, soft, chalk-like rock, without grit and composed almost entirely of $CaCO_3$	110¾-111
12-22.	Yellow, medium-grained calcareous sand, with a large percentage of shell fragments, especially *Bryozoans;* scattered grains of glauconite in some samples	111- 238
23-24.	Yellow calcareous clay, and yellow sand, like preceding	238- 249
25.	Yellow sand filled with *Bryozoan* remains, like samples 12 to 22	249- 254
Cretaceous (Peedee in part):		
26-33.	Gray, very calcareous clay, with an admixture of soft sand in last two samples	254- 418
34.	Gray, calcareous, very glauconitic sand	418- 419
35-46.	Gray calcareous clay, slightly sandy in some samples	419- 678
46½.	Mixture of gray calcareous clay, sand and fragments of shells	678- 680
47.	Samples representing 680 to 690 missing	680- 690
48-48½.	Same as 46½, but contains impure lime concretions as much as 1 inch in diameter	690- 693
49-55½.	Gray, argillaceous, calcareous sand, with numerous small shell fragments. No. 50 contains fragments of gray calcareous sand-rock	693- 795
56-57.	Dark green, very glauconitic, calcareous sand	795- 880
58.	Mixture of chunks of dark-green glauconitic sand and gray calcareous sand	880- 896
59.	Coarse gray sand, with small shell fragments	896- 899
59½.	Light gray argillaceous limestone, with casts of *Pelecypods* and *Gastropods*	896- 899
60-65½.	Gray calcareous, finely micaceous clay, large pieces of shells of *Ostrea* and *Exogyra* in last sample	899-1140
Age uncertain (possibly Lower Cretaceous in part):		
66.	Light pinkish plastic clay	1140-1160
67-68.	Samples missing	1160-1200
68½.	Gray calcareous clay, with a mixture of quartz pebbles up to ½ inch in diameter and shell fragments	1200-1237

		Feet.
69.	Clean, loose, slightly calcareous sand	1237-1253
70.	Sample missing	1253-1259
71.	Light gray calcareous clay	1259
72-73.	Light to dark pinkish or reddish finely laminated clay	1259-1322
74.	Light gray calcareous clay, with an admixture of small quartz pebbles as large as birdshot	1226-1334
75.	Coarse, argillaceous, calcareous sand	1342-1365
76-76a.	Coarse sand and gravel, with pebbles up to ⅛ inch in diameter. Also, piece of gray calcareous sand-rock and pieces of shells	1365-1380
77-78.	Very coarse sand, many of the grains as large as birdshot, with small particles of gray calcareous clay, and with numerous fragments of shells	1380-1405
79-80.	Coarse sand, with a large percentage of small particles of gray calcareous clay, scattered grains of glauconite, and numerous shell fragments, among them encrusting *Bryozoans*	1405-1440
	Total	1440

The drilling of the above well was started on September 9, 1905, and the last sample was taken April 16, 1906.

SECTION OF WELL AT QUARANTINE STATION, LOCATED ABOUT 1 MILE EAST OF SOUTHPORT, N. C., IN CENTER OF CAPE FEAR RIVER ESTUARY.*

		Feet.
Pleistocene:		
1-5.	Loose beach sand, with shells and fragments of shells, probably Pleistocene. Sample No. 4 is quite argillaceous	15- 40
6.	Light bluish-gray, iron-stained coquina rock, consisting of shells in very fragmentary condition, cemented with lime.	40- 45
7-9.	Loose beach sand, with shells and fragments of shells similar to samples Nos. 1-5	45- 60
10-11.	Chunks of gray calcareous clay, pieces of light blue coquina rock and numerous well-preserved shells of Pleistocene age.	60- 70
Eocene (Castle Hayne and Trent):		
12-15.	Bluish-gray, sandy coquina rock, the shells in a finely comminuted condition and cemented with lime. Samples Nos. 14 and 15 contain fragments of branching *Bryozoans* similar to those found in the vicinity of Wilmington. The rock is also similar lithologically to the material in which those forms occur	70- 95
16-28.	Cream colored to light bluish-gray, chalky limestone, more or less sandy in the different samples, containing *Bryozoan* forms similar to those found in the Eocene at Wilmington and vicinity	95-160
29-34.	Bluish-gray coquina-like rock consisting of comminuted fragments of *Bryozoans* and other forms cemented with lime.	160-190

*From samples furnished by the North Carolina Geological Survey.

		FEET.
35-39.	Light cream to light bluish-gray limestone rock, becoming very sandy in samples 37 and 38, containing fragments of shells and shell casts	190-215
40-47.	Light gray, very calcareous sand, with slightly indurated chunks in some samples, and in certain samples numerous fragments of fossils and fossil casts	215-265
Peedee:		
48-67.	Dark gray, very argillaceous, calcareous, fine-grained sand. (Could be classed as very arenaceous clay.) The different samples vary slightly in color, some having a bluish-gray tinge, and others a dark-brownish tinge. The lower samples become slightly less argillaceous. Finely comminuted shell fragments occur in sample No. 54	265-365
68-74.	Gray, calcareous, glauconitic sand, slightly argillaceous on upper samples, becoming coarser and very glauconitic in lower samples	365-400

MIOCENE.

ST. MARYS FORMATION.

Name.—The formation receives its name from the St. Marys River, Maryland, where its typical characteristics are well shown. The name was proposed in 1902 (Science, new ser., vol. 15, p. 906) by G. B. Shattuck.

Definition.—The St. Marys formation comprises the basal Miocene beds in North Carolina, which in some places rest upon the Eocene strata, but in other places are underlain by deposits belonging to the Cretaceous or to the crystalline rocks of the Piedmont Plateau. It is composed of unconsolidated deposits of sand, clay, and shell marls. The predominant material is a blue argillaceous sand which on weathering assumes a much lighter color. The St. Marys formation is found in the northeastern part of the State, where it forms almost continuous outcrops along the Meherrin, Roanoke, and Tar rivers. Along the Neuse River it is sparingly represented and south of the Neuse is only found in isolated patches of small areal extent.

The St. Marys formation, consisting of the lowest Miocene strata of the State, should be found normally overlying the Castle Hayne formation of the Eocene. It has not been found in contact with the Castle Hayne beds, however, for the reason that the area where that formation is now present is a region that has undoubtedly suffered much erosion since St. Marys time, and any St. Mary deposits that may have been laid down in that locality have been worn away. The St. Marys formation rests upon Trent, Cretaceous, or pre-Cambrian rocks wherever sections have been exposed within this State. Along a belt extending from

Northampton and Halifax counties on the north to Wayne County on the south the formation is in contact with the crystalline rocks of the Piedmont Plateau. In places it can be seen to rest upon an irregular surface of crystalline rocks that were probably above the water during the entire Eocene time and so did not receive any deposits belonging to that period. Along Quankey Creek, near Halifax, the St. Marys beds are in direct contact with the crystalline rocks, as shown in some of the sections which follow. In the vicinity of Rocky Mount the Miocene also occurs in small patches, filling old depressions in the crystalline rocks. Along the Neuse River to the west of Goldsboro the St. Marys probably at one time rested upon the Trent (Eocene), as the two formations are represented in that vicinity.

Along the Roanoke and Tar rivers there are many exposures where the St. Marys is found resting directly on the Cretaceous formations. Passing down the Roanoke, both the Patuxent and the St. Marys formations are exposed in certain sections, while in other sections the materials are entirely Pleistocene and Cretaceous, with the Miocene wanting, while in still other regions the Miocene extends to the water level. This rising and falling of the Cretaceous in the sections gives evidence of the irregular Cretaceous surface upon which the St. Marys was deposited. Further, the absence of the Miocene beneath the Pleistocene in other sections gives evidence of the erosion interval following the St. Marys, during which time the entire thickness of St. Marys in certain places was removed. In general, the Cretaceous formation that most commonly underlies the St. Marys is the Patuxent, though this is not always the case along the lower Tar River, as, for example, at Blue Banks Landing, where the Black Creek is directly overlain by the St. Marys beds.

Whatever formation lies beneath the St. Marys, there is in every instance a marked unconformity at its base, and the fact that it overlies beds of such varied ages indicates that there must have been a greater transgression of the ocean during St. Marys time than during the preceding periods. The absence of the St. Marys in the southern part of the State is probably due to its never having been deposited in this place, though it may be explained by its complete removal at some subsequent period.

The St. Marys formation is overlain by beds of Pleistocene age in almost every locality where exposures occur. Along the stream divides it is almost everywhere concealed from view by Pleistocene sand, gravels, and clays which are unconformable to the underlying beds.

The strata composing the St. Marys formation in North Carolina are in the main very similar, lithologically, and on the basis of lithology

alone could be separated with little difficulty from all the other formations of the Coastal Plain. The deposits consist mainly of a dark bluish-green, medium fine, argillaceous sand that contains many imprints and casts of small-sized *Mollusca*. The sand on exposure to the atmosphere changes in color, due to oxidation of the iron present, and assumes a ferruginous brown to yellow color. In certain places the iron has been almost entirely removed and the sand is gray to white in color. Normally the St. Marys sand is loose, though locally it may be indurated by a ferruginous cement. Marl beds occur in numerous places in the St. Marys, and these strata have been extensively worked in many places for fertilizing purposes. In certain localities shells are so abundant that they constitute the greater portion of the beds, but in other places the sandy matrix in which the shells are found makes up more than half the deposit. The fossils are usually rather fragile and somewhat rotten, so that they go to pieces easily and thus make very good material for the soils. During slavery days the marl deposits were worked extensively and were considered of importance, but within recent years there has been comparatively little marl dug. The reason for this is the scarcity of labor and the introduction of artificial fertilizers which act much more quickly and contain certain ingredients not found in the shell marl. The sand of St. Marys is rather fine in almost all places, though coarse sand and occasional pebbles are found near the base and along the western limits of the formation, as shown by the sections in the vicinity of Halifax, given on a later page. A pebble band is not infrequent near the base of the formation, and sometimes solitary pebbles varying up to 1 inch in diameter are found irregularly distributed through the sand some distance from the base. The coarse materials have, in almost every case, been derived from the crystalline rocks of the near vicinity, and some of them show little wearing by water. Black phosphatic pebbles and water-worn bones and sharks' teeth were probably derived from the Cretaceous or Eocene. Beside the sands and marls, there are occasional layers of sandy clay and occasional plastic clay beds interstratified with the sand.

At only one point thus far found within the State does there seem to be any evidence of diatomaceous material. This occurrence is about one mile northeast of Wrendale at the foot of a steep bank along Swift Creek. The diatomaceous earth there is decidedly sandy and grades downward into a stratum of sand.

The lithologic characteristics of the St. Marys formation are well exemplified in the numerous sections of this formation given on later pages.

Thickness.—The thickness of the St. Marys formation is exceedingly variable, due to the fact that it occupies depressions in an old land surface and also to the fact that it has suffered much erosion since its deposition. In certain places it may be 20 to 30 feet thick, while at a distance of no more than a quarter of a mile it may be absent altogether. Its greatest thickness is undoubtedly found in the northern part of the State, particularly along Meherrin and Chowan rivers. At Edenton material which probably consists mainly of St. Marys strata was found, in a well section, to extend from 10 to 230 feet. The upper part of this certainly belongs to the Yorktown formation, though probably most of it is older. From all the evidence which we have at hand at present it seems that the St. Marys formation of North Carolina is approximately 150 feet thick in its maximum development, which it attains in Hertford, Bertie, and Chowan counties, and gradually thins to a feather edge to the west and southwest, though it is about 45 feet thick at Wilson.

The lists of fossils that are given in connection with the detailed stratigraphic sections on later pages show the wide range of species found in the deposits of this formation. The marl beds previously mentioned have furnished a great abundance of well-preserved fossils, though they have not as yet been exhaustively studied. The fossils belong mainly to the group of the *Mollusca,* and of the group the *Pelecypods* are present in greatest numbers. The great abundance of *Mulinia congesta* is especially noticeable, and scarcely ever do we find an exposure of the St. Marys without finding almost as many specimens of this small *Pelecypod* as all other species combined. In certain places the marl seems to be almost entirely composed of this form. While it is not confined to the St. Marys formation, yet its remarkable development in strata of this age is diagnostic. Beside molluscan remains, much coral is found in certain localities and the remains of many marine vertebrates occur throughout the beds. Larger vertebræ of marine mammals are found in many places, while several almost complete skeletons have been reported to occur in various sections of the State. Sharks' teeth are found in many different localities, though they are not known to occur in as great abundance in this formation at any place as they do in the Castle Hayne formation in the vicinity of Wilmington.

The St. Marys formation in North Carolina forms a rather broad band extending from the North Carolina line southward to the Neuse River. Its limits westward occur along a line passing near Weldon, Halifax, Enfield, Whitakers, Rocky Mount, Wilson, and Goldsboro,

though small outliers are occasionally found several miles further west, occupying depressions in the Piedmont Plateau. Eastward it seems to extend to the ocean, though it disappears beneath the Yorktown formation along a line passing near Winton, Williamston, Washington, and Kinston. Over the area bounded by the above lines the St. Marys formation forms an almost continuous series of beds and outcrops along nearly all of the streams where erosion has removed the surficial Pleistocene deposits. In certain places, as has already been mentioned, it is wanting, and the Pleistocene there rests directly upon the Cretaceous.

South of the Neuse River the St. Marys formation seems to be wanting. It is possible, though scarcely probable, that it formed a continuous belt over the southern portion of the State, though there is now no evidence of it. In all probability the southern part of the State formed a land area during St. Marys time, and no extensive deposits referable to this formation have ever existed in that region. On the other hand, it is probable that this formation had a somewhat wider distribution at one time than it has at present, since we have evidence, stated on a previous page, of erosion removing portions of the formation in certain places. The marginal deposits would naturally be thinner, and no doubt these have been removed. Northward the St. Marys extends into Virginia, and is continued across that State into Maryland, where it has been carefully studied. In certain places it is not exposed. Between the major streams it is not exposed at the surface over any considerable areas, though it undoubtedly is present in most places over these stream divides, and it has been reached by excavations or well borings in many localities.

The structure of the St. Marys formation is decidedly simple. It is practically horizontal in almost every section exposed, though, in the main, it does descend gently toward the ocean, the dip being only slightly greater than the inclination of the surface. For this reason the formation has such a wide outcrop, though it is comparatively thin. Locally, certain beds dip at a rather high angle, though this is not common except where the materials are rather coarse. Along Tar River, where there is evidence of shallow water deposition as shown by the coarse character and the variability of the materials, local dips much greater than the average are not infrequent. In any case, however, dips exceeding 5 to 10 degrees are never found and, in most cases, the beds dip at a rate of considerably less than ten feet to the mile.

Detailed Sections.

Sections Along the Meherrin and Chowan Rivers and Their Tributaries.—St. Marys formation is exposed along the Meherrin River in a number of places in Southampton County, Va., and Northampton County, N. C. It is similar in appearance at almost every point observed. The following sections are characteristic:

SECTION ON MEHERRIN RIVER, 12 MILES FROM EMPORIA, VA.

	FEET.
Pleistocene (?):	
Concealed from view	18-20
Miocene (St. Marys):	
Light drab or gray clay, grading downward into a light-gray fossiliferous sand, fine in texture. The shell material of the fossils has been entirely removed. The sand is indurated in places near the base. Several forms of *Pelecypods* and *Gastropods* were observed	33

Marl for fertilizing purposes has been dug in this immediate vicinity.

SECTION ON MEHERRIN RIVER, 1 MILE ABOVE THE SEABOARD AIR LINE RAILROAD BRIDGE, BETWEEN BRANCHVILLE, VA., AND MARGARETTSVILLE, N. C.

	FEET.
Pleistocene:	
Yellowish loam and sand with gravel-bedded base containing bowlders of variable size	10
Miocene (St. Marys):	
Bluish-green plastic clay with casts of shells and a few fish vertebræ	2

Shell marl has also been dug in this vicinity for fertilizing purposes.

SECTION ON MEHERRIN RIVER, 2 MILES BELOW THE SEABOARD AIR LINE BRIDGE, BETWEEN BRANCHVILLE, VA., AND MARGARETTSVILLE, N. C.

	FEET.
Pleistocene (?):	
Concealed from view	10
Miocene (St. Marys):	
Greenish-gray, compact, fossiliferous, sandy clay. The fossils are fragile and difficult to collect. The most abundant form is *Mulinia congesta*	4½

The same fossiliferous bed is also exposed along the right bank of the river, ½ mile below the above section.

At Meherrin River, Branch's bridge, midway between the upper and lower Seaboard Air Line bridges, there is exposed 5 feet of dark greenish-gray sandy clay filled with fossils. The stratum is similar to the preceding section.

SECTION AT MEHERRIN RIVER, 1½ MILES BELOW BRANCHS BRIDGE.

	Feet.
Pleistocene:	
Concealed	10
Gray to yellowish-brown sand containing some gravel bands	15
Miocene (St. Marys):	
Light to dark drab, laminated clay with fine sand partings, becoming yellow in color on weathered surface	11
Dark green, slightly arenaceous clay, compact and plastic, without fossils	13
Similar material to above stratum, but containing many characteristic Miocene fossils. *Mulinia congesta* is represented by great numbers of specimens. Other *Gastropods* and *Pelecypods* are common	22

On the Meherrin River, 3 to 4 miles above the Seaboard Air Line Railway bridge, between Boykins, Va., and Severn, N. C., there are exposed 4 feet of grayish-blue sandy clay filled with shells. *Mulinia congesta* is abundant.

SECTION ON MEHERRIN RIVER, ½ TO ¾ MILE ABOVE THE SEABOARD AIR LINE RAILWAY BRIDGE, BETWEEN BOYKINS, VA., AND SEVERN, N. C.

	Feet.
Pleistocene (?):	
Concealed	25
Miocene (St. Marys):	
Reddish loamy clay	10
Yellowish sand, containing numerous fossil *Pelecypoda* and *Gastropoda; Mulinia congesta* abundant	7
Drab sandy clay	2
Concealed by talus	2
Rotten sandy shell marl containing many species of *Pelecypoda* and *Gastropoda*	5

A few hundred yards below the above section the marl at the base is well exposed and is less weathered. The matrix consists of dark green sandy clay.

SECTION A SHORT DISTANCE BELOW THE ABOVE SECTION.

	Feet.
Pleistocene (?):	
Reddish-yellow laminated clay alternating with sand	20
Light gray sandy clay, stained red in certain places	10
Miocene (St. Marys):	
Dark bluish-green sandy clay, yellow in color on weathered surfaces; filled with a large variety of fossil shells, of which *Mulinia congesta* is especially abundant	41

SECTION AT WATSON'S MILL, KIRBY'S CREEK, 2½ MILES NORTHWEST OF MURFREESBORO.

At this point the following section of Miocene is exposed overlain by Pleistocene materials:

Pleistocene:	FEET.
Thin-bedded drab to yellow sandy clay	10
Reddish-brown sand, containing fossil casts	4
Dark bluish-gray sandy clay indurated in places, containing many small *Pelecypod* shells	16

Fossil bones are reported to occur in the base of the section which was concealed from view by the high water at the time the above observations were taken.

SECTION ON MEHERRIN RIVER, 1½ MILES ABOVE MURFREESBORO.

Pleistocene:	FEET.
Reddish sandy loam, grading downward into a coarse reddish sand.	16
Miocene (St. Marys):	
Drab arenaceous clay, stained with iron at base	5
Shell bed in which the fossils are inclosed in a matrix of sandy clay bluish-green in color. The most common fossils are small *Pelecypoda*, *Mulinia congesta* being especially abundant	2½
Bluish-green sandy clay similar to above stratum, but with few fossils	10
Shell marl containing characteristic Miocene fossils inclosed in a matrix of gray to yellow sand	5
Yellow to gray sand, containing fewer fossils	5
Shell marl, matrix consisting of a dark greenish-gray sand or sandy clay. Some large bones were observed in this basal layer	2½

The following species of fossils have been determined from this locality:

GASTROPODA:
- *Cadulus thallus* Conrad.
- *Calliostoma bellum* Conrad.
- *Calliostoma briani* Conrad.
- *Calliostoma philanthropus* Conrad.
- *Crepidula aculeata* Gmelin var. *costata* Morton.
- *Crepidula plana* Say.
- *Crucibulum constrictum* Conrad.
- *Crucibulum grande* Say.
- *Dentalium attenuatum* Say.
- *Ecphora quadricostata* Say.
- *Fissuridea catelliformis* Rogers.
- *Fissuridea redimicula* Say.
- *Fossarus lyra* Conrad.
- *Ilyanassa isogramma* Dall.
- *Nassa scalaspira* Conrad.
- *Polynices duplicatus* Say.
- *Polynices heros* Say.
- *Ptychosalpinx altilis* Conrad.
- *Ptychosalpinx tuomeyi* H. C. Lea.
- *Scalaspira strumosa* Conrad.
- *Turbonilla interrupta* Totten.
- *Turritella variabilis* Conrad.

PELECYPODA:
- *Asaphis centenaria* Conrad.
- *Astarte coheni* Conrad.
- *Astarte symmetrica* Conrad.
- *Astarte undulata* Say.
- *Chama congregata* Conrad.
- *Chama corticosa* Conrad.
- *Corbula inaequalis* Say.
- *Crassatellites lunulatus* Conrad.
- *Crassatellites undulatus* Say.
- *Crepidula aculeata* Gmelin var. *costata* Morton.
- *Diplodonta subvexa* Conrad.
- *Dosinia acetabulum* Conrad.
- *Ensis directus* Conrad.
- *Gafrarium metastriatum* Conrad.

Glycymeris subovata Say.
Isocardia fraterna Say.
Melina maxillata Deshayes.
Mulinia congesta Conrad.
Nucula proxima Say.
Ostrea compressirostra Say.
Ostrea sculpturata Conrad.
Panopea reflexa Say.
Pecten clintonius Say.
Pecten decemnarius Conrad.
Pecten eboreus Conrad.
Pecten jeffersonius Say.
Pecten jeffersonius var. *edgecombensis* Conrad.
Pecten madisonius Say.
Pecten marylandicus Wagner.
Pecten rogersi Conrad.
Phacoides anodonta Say.
Phacoides crenulatus Conrad.
Phacoides contractus Say.
Pecten cribrarius Say.
Plicatula marginata Say.
Thracia conradi Couthouy.
Venericardia granulata Say.
Venus rileyi Conrad.
Venus tridacnoides Lamarck.
Yoldia laevis Say.

SECTION 1 MILE ABOVE MURFREESBORO, LEFT BANK OF MEHERRIN RIVER.

	Feet.
Pleistocene:	
Sand, partially concealed	17
Miocene (St. Marys):	
Shell marl, matrix of dark green sand, containing many fossil shells and vertebrate bones	2

Meherrin River at Murfreesboro.—The section at this point is not as well exposed as at the two localities previously described, though similar strata outcrop in the river bank. The fossils are abundant and well preserved.

FOSSILS FROM MEHERRIN RIVER BLUFFS, NEAR MURFREESBORO.

GASTROPODA:
Calliostoma philanthropus Conrad.
Crepidula aculeata Gmelin var. *costata* Morton.
Crepidula fornicata Say.
Dentalium attenuatum Say.
Ecphora quadricostata Say.
Polynices heros Say.
Aurinia mutabilis Conrad.
Turritella variabilis Conrad.
Vermetus sculpturatus H. C. Lea.
Vermetus? virginica Conrad.

PELECYPODA:
Astarte undulata Say.
Cardium laqueatum Conrad.
Cardium virginianum Conrad.
Chama congregata Conrad.
Crassitellites lunulatus Conrad.
Crassitellites undulatus Say.
Dosinia acetabulum Conrad.
Glycymeris americana de France.
Glycymeris subovata Say.
Margaritaria abrupta Conrad.
Mulinia congesta Conrad.
Ostrea compressirostra Say.
Ostrea sculpturata Conrad.
Panopea reflexa Say.
Pecten eboreus Conrad.
Pecten jeffersonius Say.
Pecten jeffersonius var. *edgecombensis* Conrad.
Pecten jeffersonius var. *septenarius* Say.
Plicatula marginata Say.
Thracia conradi Couthouy.
Venericardia granulata Say.
Venus rileyi Conrad.
Venus tridacnoides Lamarck.
Verticordia emmonsi Conrad.

SECTION AT MADDRY'S BLUFF, 1½ MILES BELOW MURFREESBORO, RIGHT BANK OF MEHERRIN RIVER.

	Feet.
Pleistocene:	
Buff sand, somewhat loamy at top and containing a few pebbles toward base	8
Miocene (St. Marys):	
Buff sand	2
Brown to blue sand, filled with specimens of *Mulinia congesta*. Certain bands are composed almost entirely of these shells	20
Drab clay with few fossils, some gypsum crystals	15
Shell marl, great variety of shells in blue sandy clay matrix	5

At Whiteley's Bluff, about 3 miles below Murfreesboro, left bank of Meherrin River, blue Miocene clay appears about 3 feet above water, overlain by about 15 feet of Pleistocene sand, poorly exposed.

Left Bank of Meherrin River, 150 Yards Below Sear's Wharf (Parker's Landing on Topographic Map).—A very compact blue Miocene clay appears in bluff 5 feet above water's edge. It contains no fossils. It is overlain by about 6 feet of Pleistocene sand.

The water seeps out of bank just above the Miocene clay, thus accentuating the contact between the Miocene and the overlying Pleistocene strata.

Chowan River Bluffs at Winton, N. C.—The bluffs consist almost entirely of Pleistocene, which is composed of clay loam at surface, beneath which is stratified and cross-bedded sand, brown and white in color and containing some clay laminæ. The sand in one place is so pure and so loose that it has been dug for building sand. Farther west from Winton, about 1 mile from the wharf, the Pleistocene consists largely of drab clay. At several places along these bluffs the Miocene is exposed, rising almost 6 feet above the water in a few places. The Miocene material consists of a compact, slightly argillaceous blue sand, in which are great numbers of fossil casts and moulds of small *Pelecypoda.* It is reported that shell marl is struck at a depth of a few feet near the river.

Bluffs on Chowan River at Petty Shore and About 1 1-2 Miles Below Petty Shore.—Bluffs at both places were examined, but exposures were very poor. No Miocene was observed, and it is believed that the Pleistocene extends to water's edge. It consists mainly of drab clay beneath the surface clay loam.

Shell marl has been reported to occur in these bluffs, but it probably lies beneath the water level, although it may occur at a higher level and be concealed by the vegetation or by materials that have slipped down from above.

SECTION JUST EAST OF CHINQUAPIN BRIDGE ON CHINQUAPIN CREEK, HERTFORD COUNTY.

	FEET.
Pleistocene:	
Buff-brown sandy clay loam	5
Miocene (St. Marys):	
Fine buff to gray stratified sand; no fossils observed	10

Sections Along the Roanoke River and Tributaries.—In a ravine, tributary to Quankey Creek, just to the south of the town of Halifax, the following section is exposed:

SECTION AT HALIFAX, N. C.

	FEET.
Pleistocene:	
Loose white sand, containing a few pebbles at the base	5½
Miocene (St. Marys):	
Light drab arenaceous and micaceous clay stained yellow in places, grading downward into next member	3½
Light yellow to white interlaminated micaceous sand and drab clay	4
Irregularly stratified dark blue plastic arenaceous and micaceous clay, arkosic in places	7-8
Partly concealed drab to gray plastic clay, containing considerable coarse arkosic sand in places	10
Dark bluish-green plastic clay, containing flakes of mica and some rather coarse sand and small pebbles; very compact. Forms a vertical wall over which the water falls	4
Dark green argillaceous sand	10-12
Shell marl, the shells inclosed in a matrix of dark bluish-green sand. The molluscan fossils are varied and abundant and constitute the larger portion of the marl, though there are many vertebrate bones present. This rests unconformably upon the irregular surface of rotten granitic rock. Some pebbles and even large bowlders are found in the marl, to one of which a number of barnacles were attached	2-6
Pre-Cambrian crystallines:	
Decayed granitic rock	10-15

FOSSILS FROM HALIFAX, N. C.

CRUSTACEA:

Balanus concavus Bronn.

GASTROPODA:

Calliostoma philanthropus Conrad.
Calliostoma philanthropus var. *basicum* Dall.
Crepidula aculeata Gmelin var. *costata* Morton.
Crepidula fornicata Say.
Crucibulum grande Say.
Crucibulum costatum var. *pileolum* H. C. Lea.
Ecphora quadricostata Say.
Fissuridea marylandica Conrad.
Fissuridea redimicula Say.
Polynices heros Say.
Scala marylandica Dall.
Teinostama nanum H. C. Lea.
Tornatina canaliculata Say.
Turritella variabilis Conrad.

SCAPHOPODA:

Cadulus thallus Conrad.
Dentalium attenuatum Say.

PELECYPODA:

Anomia simplex d'Orbigny.
Arca (Barbatia) centenaria Say.

Asaphis centenaria Conrad.
Astarte symmetrica Conrad.
Astarte undulata Say.
Cardium virginianum Conrad.
Cardium laqueatum Conrad.
Cardium sp.
Chama congregata Conrad.
Corbula inaequalis Say.
Crassatellites undulatus Say.
Diplodonta subvexa Conrad.
Dosinia acetabulum Conrad.
Ensis directus Conrad.
Glycymeris suborata Say.
Leda acuta Conrad.
Mulinia congesta Conrad.
Ostrea carolinensis Conrad.
Ostrea compressirostra Say.
Ostrea sculpturata Conrad.
Panopea reflexa Say.
Pecten decemnarius Conrad.
Pecten eboreus Conrad.
Pecten jeffersonius Say.
Pecten jeffersonius var. *edgecombensis* Conrad.
Pecten jeffersonius var. *septenarius* Say.
Pecten madisonius Say.
Pecten rogersi Conrad.
Pecten n. sp.
Phacoides contractus Say.
Phacoides anodonta Say.
Phacoides crenulatus Conrad.
Phacoides cribrarius Say.
Venericardia granulata Say.
Venus rileyi Conrad.
Venus tridacnoides Lamarck.
Yoldia laevis Say.

SECTION 150 YARDS BELOW BRIDGE ACROSS QUANKEY CREEK AT HALIFAX.

	Feet.
Pleistocene:	
Slope covered with vegetation and wash, upper part undoubtedly Pleistocene	25
Miocene (St. Marys):	
Blue sand, weathering to yellow	4
Somewhat fragile shells in matrix of blue sand. The sand contains many rounded and some angular quartz pebbles as much as 1 inch in diameter, resting upon an uneven surface of decayed crystallines	3½
Decayed crystallines extending to water's edge	8-10

At occasional intervals along Quankey Creek, above the A. C. L. Railroad bridge, the Miocene can be seen resting with a marked unconformity upon decayed granitic rocks. The exposures are at places where the creek has washed against the banks. At some points thus exposed a thin layer of very rotten shell marl can be seen resting directly upon the granite. The material above the marl consists in most places of dark green sand or clay, or its weathered product. For the whole distance of ½ mile above the bridge the surface of the granite is about 8 or 10 feet above the bed of the creek. It undulates slightly, but in general is almost parallel to the grade of the stream. Near the mouth of a small branch entering from the west or southwest, ½ mile above the railroad bridge, the marl was observed to be about 3 feet thick. Up this creek ⅛-¼ mile are good exposures of shell marl with a variety of Miocene fossils. The matrix consists of dark gray sandy clay. Marl deposits are reported still farther up Quankey Creek.

A.—Exposure showing the Patuxent formation overlain unconformably by the St. Marys formation, and the latter in turn overlain by Pleistocene deposits, Roanoke River, one mile above the State Farm, Halifax County, N. C.

B.—Bluff at Blue Banks Landing, Tar River, seven miles above Greenville, N. C., showing the Black Creek formation overlain by the St. Marys formation.

SECTION ON ROANOKE RIVER, 5 MILES BELOW HALIFAX, 1 MILE ABOVE STATE FARM LANDING.

	FEET.
Pleistocene:	
Concealed	6
Stratified yellow sand, containing pebble layers	17½
Miocene (St. Marys):	
Dark green compact sandy clay containing a few fossil casts, grading downward into a greenish-gray argillaceous sand containing a few small pebbles at the base	10
Cretaceous (Patuxent):	
Gray micaceous arkosic sand, with some lignite, exposed	4

SECTION A FEW HUNDRED YARDS BELOW THE PRECEDING, RIGHT BANK OF ROANOKE RIVER.

	FEET.
Pleistocene:	
Sand and gravel strata alternating, resting unconformably upon the Miocene	22
Miocene (St. Marys):	
Dark bluish-green arenaceous clay containing small flakes of mica and a few fossil casts, resting unconformably upon the Cretaceous	3-3½
Cretaceous (Patuxent):	
Coarse, arkosic sand, exposed	12

SECTION ON ROANOKE RIVER, BELOW MUDHOLE LANDING, 10¼ MILES BELOW HALIFAX.

	FEET.
Pleistocene:	
Poorly exposed gravel band, containing cobbles and bowlders at base	22
Miocene (St. Marys):	
Stratified gray sandy micaceous clay interlaminated with gray, yellowish-brown sand, laminæ several inches thick	7
Band of small pebbles not well exposed	1½

SECTION ON RIGHT BANK OF ROANOKE RIVER, EDWARD'S FERRY, 102¼ MILEPOST.

	FEET.
Pleistocene:	
Poorly exposed strata, gravel band at base; rests unconformably upon the Miocene	18-20
Miocene (St. Marys):	
Dark bluish-green micaceous plastic clay with a few indistinct fossil imprints and a few small fish vertebræ. At the base there is a thin line of small pebbles containing a few larger ones, some of which are 2 to 3 inches in diameter. The contact between this stratum and the underlying Cretaceous sand is an undulating line varying from 4 to 8 feet above the water, and in a few places the Miocene is entirely absent. A few fragments of the Cretaceous materials have been included in the base of the Miocene	0-4
Cretaceous (Patuxent):	
Light drab micaceous, arkosic sand	4-8

PLEISTOCENE AND MIOCENE SECTION AT PALMYRA, ROANOKE RIVER.

	Feet.
Pleistocene:	
Surface clay loam, grading downward into a buff to yellow sandy clay	7
Loose interbedded white and yellow cross-bedded sands, containing numerous clay laminæ toward base in certain parts of the section	12
Compact drab clay, containing fragmental plant remains	3
Gravel layer with occasional cobbles 6 inches in diameter	½
Miocene (St. Marys):	
Fine, loose white, gray, buff, and greenish-gray sands, blotched with iron stains	33
Blue argillaceous sand	2½
Blue argillaceous sand filled with fossil shells and containing many bones, especially near the base	7
Cretaceous:	
Blue argillaceous sand without fossils	2

FOSSILS FROM PALMYRA BLUFF.

CRUSTACEA:
Balanus concavus Bronn.
GASTROPODA:
Calliostoma philanthropus Conrad.
Calliostoma ruffini H. C. Lea.
Crepidula aculeata Gmelin.
var. *costata* Morton.
Crepidula fornicata Say.
Crepidula sp.
Crucibulum constrictum Conrad.
Ecphora quadricostata Say.
Fossarus lyra Conrad.
Lirosoma sulcosa Conrad.
Polynices heros Say.
Aurinia mutabilis Conrad.
Turritella variabilis Conrad.
Vermetus graniferus Say.
SCAPHOPODA:
Cadulus thallus Conrad.
Dentalium attenuatum Conrad.
PELECYPODA:
Asaphis centenaria Conrad.
Astarte exaltata Conrad.
Astarte symmetrica Conrad.
Astarte undulata Say.
Astarte vicina Say.
Callocardia sayana Conrad.
Cardium laqueatum Conrad.
Cardium virginianum Conrad.
Chama congregata Conrad.
Chione cribraria Conrad.
Corbula cuneata Say.
Corbula inaequalis Say.
Crassatellites lunulatus Conrad.
Crassatellites undulatus Say.
Diplodonta subvexa Conrad.
Dosinia acetabulum Conrad.
Ensis directus Conrad.
Ensis ensiformis Conrad.
Gemma magna Dall.
Gemma trigona Dall.
Glycymeris americana de France.
Glycymeris subovata Say.
Leda acuta Conrad.
Macrocallista albaria Say.
Mulinia congesta Conrad.
Nucula proxima Say.
Ostrea compressirostra Say.
Ostrea sculpturata Conrad.
Panopea reflexa Say.
Pecten eboreus Conrad.
Pecten jeffersonius Say.
Pecten jeffersonius var. *edgecombensis* Conrad.
Pecten madisonius Say.
Pecten jeffersonius var. *septenarius* Say.
Petricola carolinensis Conrad.
Phacoides anodonta Say.
Phacoides crenulatus Conrad.

Phacoides contractus Say.
Phacoides cribrarius Say.
Rangia clathrodonta Conrad.
Spisula magnoliana Dall.
Thracia conradi Couthouy.
Venericardia granulata Say.
Venericardia tridentata Say.
Venus rileyi Conrad.
Yoldia lævis Say.

Right Side of Roanoke River, 3 1-2 Miles Below Palmyra.—Fossiliferous blue sandy clay belonging to the St. Marys formation rises about 7 feet above high water. It may be the same layer exposed at Palmyra, though it contains a somewhat different assemblage of fossils.

FOSSILS FROM 3½ MILES BELOW PALMYRA LANDING.

CRUSTACEA:
Balanus concavus Bronn.
GASTROPODA:
Crepidula fornicata Linné.
PELECYPODA:
Leda acuta Conrad.
Mulinia congesta Conrad.
Nucula proxima Say.
Ostrea compressirostra Say.
Phacoides crenulatus Say.
Yoldia laevis Say.

SECTION AT UPPER END OF ROANOKE RIVER BLUFF AT HAMILTON, JUST ABOVE LANDING.

	FEET.
Pleistocene:	
Clay sandy loam with some sand layers and some layers of pure clay	12
Miocene (St. Marys):	
Lens of fossiliferous sandy clay which at greatest thickness is about 3½ feet. Consists in some places of indurated shell fragments. *Ensis*, *Nucula*, and *Leda* are the most abundant fossils.	0-3½
Greenish-gray argillaceous sand containing several fossil bands similar to above and some isolated shells	13

In several places in the Hamilton Bluffs, especially in the lower portion of the bluff, many layers of shell fragments occur. In one place a layer was seen largely composed of fragments of *Venus*.

FOSSILS FROM HAMILTON BLUFFS.

GASTROPODA:
Cadulus thallus Conrad.
Calliostoma mitchelli Conrad.
Calliostoma philanthropus Conrad.
Calliostoma virginicum Conrad.
Olivella nitidula Dillwyn.
Polynices heros Say.
Scalaspira strumosa Conrad.
Teinostoma nanum H. C. Lea.
Tornatina canaliculata Say.
Turbonilla interrupta Totten.
Turritella variabilis Conrad.
PELECYPODA:
Anomia simplex d'Orbigny.
Arca improcera Conrad.
Corbula inaequalis Say.
Ensis directus Conrad.
Gemma trigona Dall.
Glycymeris subovata Say.
Leda acuta Conrad.
Mulinia congesta Conrad.
Nucula proxima Say.
Ostrea sculpturata Conrad.
Panopea americana Conrad.
Pecten eboreus Conrad.
Phacoides crenulatus Conrad.
Plicatula marginata Say.
Venericardia granulata Say.
Venus rileyi Conrad.
Yoldia laevis Say.

At Poplar Point Landing, Roanoke River, the Miocene is exposed above water (high water) and consists of finely laminated, interbedded drab clays and yellowish-brown sand.

Williamston, N. C.—There are many marl pits about the town and surrounding country. Years ago great quantities were dug every year and spread on the land, but now comparatively little is used. George Whitley, 1 mile west of town, still uses considerable. A drainage ditch on the farm of Joseph Cherry, about 2 miles northwest of town, was visited, where the marl was exposed. The marl appears at the inner edge of the first terrace above the river bottom. It is about 8 feet in thickness and consists of shells, many fragmentary, in a matrix of greenish-blue sand. The marl is said to be 8 feet thick. Above are buff, white, and yellow loose Miocene sand. No section was noticed where the thickness of Pleistocene could be determined, but it is believed to be not more than 15 to 20 feet in thickness at the most.

FOSSILS FROM 2½ MILES NORTHWEST OF WILLIAMSTON.

GASTROPODA:
- *Cadulus thallus* Conrad.
- *Calliostoma philanthropus* Conrad.
- *Crepidula aculeata* Gmelin var. *costata* Morton.
- *Crepidula fornicata* Say.
- *Dentalium attenuatum* Say.
- *Olivella mutica* Say.
- *Polynices duplicatus* Say.
- *Teinostoma nanum* H. C. Lea.
- *Terebra dislocata* Say.
- *Turbonilla interrupta* Totten.
- *Turritella variabilis* Conrad.

PELECYPODA:
- *Arca improcera* Conrad.
- *Arca limula* Conrad.
- *Arca limula* var. *filosa* Conrad.
- *Astarte concentrica* Conrad.
- *Astarte symmetrica* Conrad.
- *Callocardia sayana* Conrad.
- *Corbula cuneata* Say.
- *Corbula inaequalis* Say.
- *Crassatellites undulatus* Say.
- *Crepidula aculeata* Gmelin var. *costata* Morton.
- *Cumingia medialis* Conrad.
- *Diplodonta acclinis* Conrad.
- *Diplodonta yorkensis* Dall.
- *Divaricella quadrisulcata* d'Orbigny.
- *Donax emmonsi* Dall.
- *Ensis directus* Conrad.
- *Ensis ensiformis* Conrad.
- *Glycymeris americana* de France.
- *Glycymeris subovata* Say.
- *Mulinia congesta* Conrad.
- *Ostrea sculpturata* Conrad.
- *Pecten eboreus* Conrad.
- *Phacoides crenulatus* Conrad.
- *Phacoides cribrarius* Say.
- *Plicatula marginata* Say.
- *Rangia clathrodonta* Conrad.
- *Spisula subparilis* Conrad.
- *Tellina declivis* Conrad.
- *Transenella carolinensis* Dall.
- *Venericardia granulata* Say.
- *Venus rileyi* Conrad.
- *Yoldia laevis* Say.

One mile northwest of Williamston, Martin County, the marl has been dug along a branch where it was reached at a depth of from 5 to 7 feet.

SECTION 4 MILES NORTHWEST OF WILLIAMSTON, ALONG CONOHO CREEK.

	Feet.	Inches.
Pleistocene:		
Loose, black, sandy loam	1	
Gray iron-stained clay, becoming more sandy toward the base	5	
Plastic drab clay	1½	
Coarse, loose, ferruginous sand	...	1
Loose gray sand, colored with iron in places	3	
Miocene (St. Marys):		
Band of ferruginous sand passing downward into a bluish-drab argillaceous sand	5	
Greenish-blue to gray sand, containing many fossil shells exposed in ditch by roadside	1	

Three Miles West of Williamston, Martin County.—A shell marl bed outcrops along the road at this point in which specimens of *Pecten eboreus* are common.

SECTIONS ALONG FISHING AND SWIFT CREEKS AND THEIR TRIBUTARIES.

One-half mile west of Enfield on the farm of J. H. Sherrod, a few shells were found about an old marl pit. The marl seems to consist almost entirely of *Mulinia congesta* and is very similar to the marls at Rocky Mount and Wilson. The matrix of the shells seems to be a blue sandy clay similar to that at Rocky Mount. Marl has also been dug to the north and east of Enfield.

In the vicinity of Enfield, along Fishing Creek and its tributaries, the St. Marys Miocene is found practically everywhere by digging a few feet in the flood plain of the stream. It consists of a bluish-green argillaceous sand filled with fossils, and has been dug for fertilizing purposes in a great many places, though at present it is not being worked. It seldom outcrops. It seems probable that the deposit is a continuous one in this section. The St. Marys Miocene at Enfield is rather thick, as a 10-foot bed of Miocene marl was struck in digging a well at a depth of 60 feet.

Fishing Creek, 3 1-2 Miles Northeast of Leggett's Postoffice.—The river here flows along the third Pleistocene terrace, which is about 70 feet above the river. The bluff is concealed by vegetation to within 6 feet from the water, where Miocene fine blue sand, containing casts of fossils, is exposed. Some of the sand has been oxidized to an orange-yellow color. In the fine sand a few well-rounded quartz pebbles as much as an inch in greatest diameter occur.

SECTION ON FISHING CREEK, RIGHT BANK, ONE-THIRD MILE BELOW MABREY BRIDGE.

	Feet.
Pleistocene:	
Brown sandy loam, grading into next member	4
Medium fine gray to brown sand, loose in texture	3½

	Feet.
Very coarse white to buff loose sand, containing numerous small pebbles and a few blocks of rock 6 inches in diameter........	4
Miocene (St. Marys):	
Blue to buff (when weathered) fine sand, containing occasional rounded quartz pebbles, some as much as 1 inch in diameter. In upper 3 inches the sand is somewhat indurated and in this layer a few fossil impressions occur. *Pecten* and *Astarte* were recognized. Exposed to water's edge........................	8

The Miocene in the above section is similar to that at Shiloh Mills in which fossil shells are found, but is quite unlike that between Bell's Bridge and Dunbar Bridge.

Three Miles South of Battleboro on Road Between Battleboro and Rocky Mount, at Stream Crossing.—A series of marl pits is found here, though the marl was not observed in place. It evidently does not outcrop. The fossils indicate that the stratum is similar to the other St. Marys marl of this vicinity. *Mulinia congesta* is especially abundant.

One and One-fourth Miles East of Battleboro on a Tributary of Swift Creek.—On the land of H. B. Brown marl has been dug in several places. The marl does not outcrop, but is found underlying the stream valleys and can be obtained by removing about 5 feet of overburden. The fossils found in this marl are similar to those present in the marl about Rocky Mount.

Swift Creek, 1 Mile Northeast of Wrendale.—At this point the bluff is about 45 feet in height. The upper part is undoubtedly Pleistocene and is part of the second terrace, but on account of the vegetation it does not show.

	Feet.
Pleistocene (?):	
Concealed by vegetation....................................	35
Miocene (St. Marys):	
Sandy diatomaceous earth, grading into lower member...........	4
Buff to blue fine sand..	12
Blue sand filled with *Mulinia congesta*, with a few specimens of *Pecten eboreus*..	1
Concealed to water's edge....................................	2

Swift Creek, 2 Miles Above Hemmed Island.—At base of 12-foot bank shell marl outcrops. About 1 foot is exposed. It consists of blue sand well filled with perfect shells. The material resembles that exposed 1/2 mile above Bell's Bridge, except that *Divaricella quadrisulcata* does not appear.

SECTIONS ALONG TAR RIVER AND ITS TRIBUTARIES.

Tributary of Tar River, 3 1-2 Miles Northwest of Rocky Mount.—Marl has been dug in many places along this stream and has been

spread on the land, though none has been dug for 20 years. Some fossil shells were found about an old marl pit. Specimens of *Mulinia congesta* are especially abundant. The shells are evidently found in a blue sandy clay. The marl occurs about 4 feet below the surface and pit is full of water. There are old marl pits on the opposite side of the stream also. The marl resembles that at Wilson. Crystalline rocks appear at same level 50 yards upstream, thus indicating the Miocene to have been deposited in depressions in the Piedmont surface.

Old Marl Pits, 2 Miles West of Rocky Mount, on Small Branch of Tar River, 1-2 Mile West of the River and Just North of Springhope Branch of the A. C. L. Railroad.—There are here a number of old pits where marl was dug by a Mr. McDaniel before the war. These are evidently the pits to which Emmons refers in his 1852 report. The pits are now filled with water and decaying vegetation and the marl is nowhere exposed. But about some of the pits, beneath the covering of vegetable loam, some of the old marl was seen. It consists of shells, *Mulinia congesta* principally, in a matrix of greenish-gray (perhaps, originally, greenish-blue) sandy clay, with a very few small quartz pebbles. Other shells observed were *Pecten eboreus, Venus, Turritella, Balanus, Ostrea, Dentalium, Arca,* etc. No crystalline rocks are exposed here, though they do outcrop a short distance away.

Two and One-half Miles Northwest of Rocky Mount; Tributary of Tar River.—Marl has been dug at this place, though it does not outcrop. Various species of fossil shells were contained in the marl, principally *Ostrea, Venus,* and *Mulinia congesta.*

Tributary of Tar River, 1-4 Mile North of Rocky Mount Waterworks.—Old marl pits are present at this place, though the marl was not seen in place.

Three-fourths Mile Northwest of Rocky Mount Waterworks.—A shallow well at this place penetrated a marl bed 3 to 4 feet from the surface. *Mollusca* and corals are the most abundant fossils in the marl.

Two-thirds Mile North of New Bridge Over the Tar River, 3 Miles Northeast of Rocky Mount.—Marl was dug in this vicinity before the war. The most abundant fossil is *Mulinia congesta.*

Along Compass Creek marl of a bluish-drab color composed of fossil shells is found; *Mulinia congesta* is specially abundant, inclosed in a matrix of fine argillaceous sand.

RIGHT BANK OF TAR RIVER, 5 MILES BELOW NEW BRIDGE.

	Feet.	Inches.
Pleistocene:		
Concealed by vegetation	8	
Miocene (St. Marys):		
Gray calcareous clay, becoming sandy at base and grading down into next member	4	

	Feet.	Inches.
Gray calcareous and argillaceous sand, becoming very coarse at base	1	
Fine gray calcareous sand, streaked with yellow iron-stained sand	1½	
Coarse stratified iron-stained sand, becoming gravelly at base, with small pebbles	3	
Fine iron-stained sand	...	3
Shell marl in sand matrix, containing many characteristic Miocene fossils	4	

FOSSILS FROM TAR RIVER, 5 MILES BELOW NEW BRIDGE.

CRUSTACEA:
Balanus concavus Bronn.

GASTROPODA:
Crepidula fornicata Say.
Turritella variabilis Conrad.

SCAPHOPODA:
Cadulus thallus Conrad.
Dentalium attenuatum Say.

PELECYPODA:
Arca improcera Conrad.
Mulinia congesta Conrad.
Ostrea sculpturata Conrad.
Pecten eboreus Conrad.
Pecten jeffersonius var. *edgecombensis* Conrad.
Pecten madisonius Say.
Phacoides crenulatus Conrad.
Phacoides radians Conrad.
Crassatellites undulatus Say.
Diplodonta acclinis Conrad.
Ostrea compressirostra Say.
Ostrea sculpturata Conrad.
Pecten eboreus Conrad.
Pecten jeffersonius Say.
Pecten madisonius Say.
Plicatula marginata Say.
Venericardia granulata Say.

PELECYPODA:
Ostrea compressirostra Say.
Ostrea sculpturata Conrad.
Pecten jeffersonius var. *edgecombensis* Conrad.

Right Bank of the Tar River, 1-2 Mile Below Mouth of Buck Swamp. In ravine there is a section exposed as follows:

	Feet.
Pleistocene:	
Gray sand, in some places loamy, and with many small pebbles	12-15
Miocene (St. Marys):	
Drab clay	5
White sand	5
Blue clay, very compact	12
Blue clay with shell impressions and gypsum crystals	2
Fossil layer, shells (*Pecten*, *Ostrea*, etc.), very rotten and in places shell substance removed and the matrix of sand slightly indurated	1½
Mud-covered slope to water (water 7 feet higher than normal)	1

TAR RIVER, TARBORO SHEET, N. C., 6¼ MILES BELOW NEW BRIDGE, RIGHT BANK.

Miocene (St. Marys):	
Concealed	5-10
Yellow stratified sand and drab clay, not well exposed	10
Dark greenish drab, argillaceous sand, very fossiliferous in lower 2 feet. *Mulinia congesta* is very abundant	7

	FEET.
Sandy clay, same color as preceding, compact, and contains fossils in some layers which are poorly preserved. The forms recognized are same as mentioned above	8

FOSSILS FROM TAR RIVER, 6 MILES BELOW NEW BRIDGE.

CRUSTACEA:
Balanus concavus Bronn.
GASTROPODA:
Crepidula aculeata Gmelin.
var. *costata* Morton.
Crucibulum costatum var. *pileolum* H. C. Lea.
Ecphora quadricostata Say.
Fossarus lyra Conrad.
Polynices duplicatus Say.
Polynices heros Say.
Turritella variabilis Conrad.
Vermetus graniferus Say.
SCAPHOPODA:
Cadulus thallus Conrad.
Dentalium attenuatum Say.
PELECYPODA:
Arca centenaria Say.
Arca plicatura Conrad.
Asaphis centenaria Conrad.
Astarte concentrica Conrad.
Astarte undulata Say.
Callocardia sayana Conrad.
Cardium laqueatum Conrad.
Chama congregata Conrad.
Corbula inaequalis Say.
Crassatellites undulatus Say.
Divaricella quadrisulcata d'Orbigny.
Ensis directus Conrad.
Glycymeris subovata Say.
Isocardia fraterna Say.
Mulinia congesta Conrad.
Ostrea sculpturata Conrad.
Pecten eboreus Conrad.
Pecten jeffersonius Say.
Pecten madisonius Say.
Phacoides anodonta Say.
Phacoides contractus Conrad.
Phacoides cribrarius Say.
Phacoides crenulatus Conrad.
Plicatula marginata Say.
Semele subovata Say.
Venericardia granulata Say.
Venus mercenaria Conrad.
Venus tridacnoides Lamarck.

TAR RIVER, ABOUT 1½ MILES ABOVE DUNBAR BRIDGE.

	FEET.
Pleistocene (?):	
Concealed by vegetation	12
Miocene (St. Marys):	
Yellowish-gray sand	9
Drab clay containing lenses of sand	1
Grayish drab, argillaceous sand	1
Gray sand, stained yellow, and indurated, in places, by iron.	4

TAR RIVER, ONE-HALF MILE ABOVE DUNBAR BRIDGE.

	FEET.	INCHES.
Surface soil	...	6
Miocene (St. Marys):		
Coarse light gray sand, indurated somewhat in lower 1 foot.	2	
Sand and clay, interstratified, and colored bright red and yellow by iron stain, the clay predominating in upper half, and the sand in lower half	8	
Coarse sand colored red and yellow in upper half by iron stain, and light yellow and greenish-gray in lower half	20	

The two preceding sections are essentially alike, and agree lithologically with the sections in which Miocene fossils were found.

One-half Mile North of Cokey Swamp, 7 Miles West of Tarboro.—In a road-side ditch, about 2 feet of iron-stained sandy Miocene clay appears, in which are numerous fossil impressions. It is overlain by thinly laminated drab clay containing fine partings of brown sand. The Miocene, lithologically, is very similar to the Miocene strata outcropping along the Tar River near Tarboro. The Miocene marl has been dug at a number of places in the vicinity of Sasnett Mill Branch, and fragments of the old shells can be seen in the fields in that vicinity.

FIRST BEND OF RIVER ABOVE BELL'S BRIDGE, LEFT BANK.

	Feet.	Inches.
Pleistocene:		
Loam and flood plain material poorly exposed............	2-4	
Miocene (St. Marys):		
Marl bed, shells perfectly preserved and representing a large fauna in matrix of fine blue to drab sand, containing quartz pebbles 1 inch or more in diameter. Near the upper part of the bed is a layer in which *Divaricella quadrisulcata* is extremely abundant. Exposed to water's edge	5	6

TAR RIVER, NEAR BELL'S BRIDGE.

GASTROPODA:

Cadulus thallus Conrad.
Calliostoma philanthropus Conrad.
Crepidula aculeata Gmelin var. *costata* Morton.
Crepidula fornicata Say.
Crepidula plana Say.
Crucibulum constrictum Conrad.
Dentalium attenuatum Say.
Ecphora quadricostata Say.
Fossarus lyra Conrad.
Polynices duplicatus Say.
Teinostoma lenticulare H. C. Lea.
Tornatina canaliculata Say.
Turbonilla interrupta Totten.
Turbonilla reticulata C. B. Adams.
Turritella variabilis Conrad.
Vermetus graniferus Say.
Vermetus sculpturatus H. C. Lea.

PELECYPODA:

Arca centenaria Say.
Arca improcera Conrad.
Arca plicatura Conrad.
Asaphis centenaria Conrad.
Astarte concentrica Conrad.
Astarte symmetrica Conrad.
Astarte undulata Say.
Callocardia sayana Conrad.
Cardium laqueatum Conrad.
Cardium sp.
Chama congregata Conrad.
Corbula cuneata Say.
Corbula inaequalis Say.
Crassatellites lunulatus Conrad.
Crassatellites undulatus Say.
Cumingia medialis Conrad.
Diplodonta acclinis Conrad.
Diplodonta subvexa Conrad.
Divaricella quadrisulcata d'Orbigny.
Dosinia acetabulum Conrad.
Ensis directus Conrad.
Gemma magna Dall.
Glycymeris subovata Say.
Isocardia fraterna Say.
Leda acuta Conrad.
Macrocallista albaria Say.
Modiolus ducatelii Conrad.
Mulinia congesta Conrad.

Nucula proxima Say.
Ostrea compressirostra Say.
Ostrea sculpturata Conrad.
Pandora crassidens Conrad.
Panopea reflexa Say.
Pecten eboreus Conrad.
Pecten jeffersonius Say.
Pecten jeffersonius var. *edgecombensis* Conrad.
Pecten jeffersonius var. *septenarius* Say.
Pecten madisonius Say.
Phacoides anodonta Say.
Phacoides crenulatus Conrad.
Phacoides contractus Say.
Phacoides cribrarius Say.
Phacoides trisulcatus Conrad.
Plicatula densata Conrad.
Plicatula marginata Say.
Semele subovata Say.
Tellina declivis Conrad.
Venericardia granulata Say.
Venericardia tridentata Say.
Venus rileyi Conrad.
Venus tridacnoides Lamarck.
Yoldia laevis Say.

RIGHT BANK OF TAR RIVER, 125 YARDS BELOW BELL'S BRIDGE.

	Feet.
Pleistocene:	
Coarse gray sand, about	10
Miocene (St. Marys):	
Gray to drab clay, somewhat resembling diatomaceous earth	12
Indurated marl layer in which all the shells have been removed, leaving only moulds	1
Shell bed, shells in matrix of olive-green to brown sand. *Pectens* especially abundant. Some phosphatic pebbles, and some grains of glauconite occur in the matrix	9
No exposure to water	5

River was 7 feet above normal at time this section was taken.

FOSSILS FROM TAR RIVER, 125 YARDS BELOW BELL'S BRIDGE.

CRUSTACEA:
Balanus concavus Bronn.
GASTROPODA:
Crepidula fornicata Linné.
Marginella bella Conrad.
SCAPHOPODA:
Dentalium attenuatum Say.
PELECYPODA:
Arca improcera Conrad.
Corbula inaequalis Say.
Mulinia congesta Conrad.
Ostrea sculpturata Conrad.
Phacoides contractus Say.
Phacoides crenulatus Conrad.
Phacoides trisulcatus var. *multistriatus* Conrad.
Venericardia granulata Say.

RIGHT BANK OF TAR RIVER, 2½ MILES BELOW BELL'S BRIDGE.

	Feet.
Pleistocene:	
Loamy gray sand containing quantities of small pebbles in certain places	10-12
Miocene (St. Marys):	
Light drab clay	7
Sandy clay, containing impressions of shells	1
Iron-stained, slightly indurated sand, containing many shell impressions	3
Blue argillaceous sand, containing numerous fossils well preserved	10
Iron-stained sand without fossils exposed to water's edge	6

Tar River, 1 1-2 Miles Below A. C. L. Railroad Bridge.—At the turn in the river, about 3½ feet of blue Miocene sand appears below about 10 feet of loamy iron-stained Pleistocene sand, the lower foot of which is decidedly pebbly.

SHILOH MILLS, TAR RIVER.

	Feet.
Pleistocene:	
Brown sandy loam, grading downward into brown sand containing numerous very small pebbles, sand distinctly laminated	10
Miocene (St. Marys):	
Blue argillaceous fine sand	3½
Shell bed; perfect shells in matrix of blue sand, grading downward into lower member, a few well-rounded quartz pebbles as much as 1 inch in diameter	3½
Fine blue sand, weathering to gray in color, containing a few shells, grading into member below	4
Shell bed, perfect shells containing species similar to shell bed above. Near base there is a well-defined layer of *Ostrea sculpturata*. Also, in lower part extending up 1-2 feet, are a great many well-rounded quartz pebbles, some more than an inch in diameter; pieces of lignite, 1 piece 2½ feet long and 6 inches in diameter; fragments of large bones, moderately water-worn, and large sharks' teeth	3-5
Undulating contact.	
Cretaceous:	
Greenish-gray micaceous clay exposed to water's edge, rather low water	3½-5

Farm of L. E. Fountain, 1 Mile Southwest of Tarboro.—Marl is found all along bed of stream, and a few shells were collected. The fossils are contained in a matrix of blue sand as along Tar River. The marl is overlain by yellowish-brown sand, which is probably blue where unweathered. Along road the Miocene is overlain by cross-bedded gray Pleistocene sand containing some small pebbles.

TOWN CREEK, SOUTH OF WIGGINS CROSSROADS.

Along the roadside the following section is exposed:

	Feet.
Pleistocene:	
Mottled red and drab loam	2-4
Buff sand with some thin lenses of drab clay	4½
Coarse arkosic buff to white sand, containing thin pebble lenses in places	8-10
Miocene (St. Marys):	
Blue compact and plastic clay. As it weathers there is a tendency for it to break up into thin laminæ and become drab in color, exposed	5

TAR RIVER, RIGHT BANK, 1 MILE BELOW OLD SPARTA BRIDGE.

In a ravine the following section was observed:

	Feet.
Pleistocene:	
Sandy loam, mainly covered with vegetation	15
Miocene (St. Marys):	
Tough blue clay, containing a few shell impressions in certain layers	10
Blue clay filled with shells similar to those seen about Tarboro	12
Blue clay without fossil shells, about	5
Cretaceous:	
Slate-colored clay, breaking irregularly and grading into a sand containing some small pebbles, exposed	7
Mud-covered slopes to river, about	8

Marl Pit of W. R. Horn, 1 1-4 Miles Northeast of Farmville.—Mr. Horn has recently dug marl here, and there is a pile of marl by the pit. Marl is similar to that on Pinelog Branch. The shell bed is 8 feet thick and is overlain by about 6 feet of Pleistocene loam and sand.

Marl Pits on East Side of Pinelog Branch, 8 1-2 Miles West of Greenville.—Old pits are located here, from which great quantities of marl have been dug. The pits are filled with water, but beside two of the pits which have evidently been worked recently (within a few years) there are piles of marl. The shells are well preserved and occur in a matrix of greenish-gray fine sand. Portions containing *Pecten eboreus,* mainly, are quite firmly indurated. Small black phosphatic pebbles are present. Specimens of *Mulinia congesta* are unusually abundant. The marl is only a few feet thick, and evidently the Cretaceous is near the surface, as a small specimen of *Exogyra* was found beside the pit.

BLUE BANKS LANDING, TAR RIVER, ABOUT 6 MILES NORTHWEST OF GREENVILLE.

	Feet.
Pleistocene:	
Very coarse, light yellowish to white, arkosic sand	8
Miocene (St. Marys):	
Light yellow, stratified sand, with some thin drab clay layers at top, poorly exposed	20
Thinly laminated dark blue clay and light gray sand, the latter micaceous and, in places, iron-stained	0-4
Coarse sand, light yellow at top with pockets of blue sand and becoming dark bluish-green in lower half. Contains pieces of bones, phosphate pebbles, quartz pebbles, sharks' teeth, large coprolites, etc.	0-1
Cretaceous:	
Dark green micaceous glauconitic sand to water's edge	18-24

The two lower layers of the Miocene fill a basin in the underlying Cretaceous and are only present in part of the bluff. The Miocene is separated from the underlying Cretaceous by a well-marked unconformity. (See Plate IX, B, opposite p. 209.)

Road Crossing of Sam's Branch, 5 Miles Northwest of Greenville.—Exposed along roadside is a thickness of about 15 feet of Miocene drab clay stained with iron along cracks and overlain by about 20 feet of cross-bedded coarse brown to white Pleistocene sand. This drab clay is distinctly laminated and contains lenses of coarse gray to buff sand. The clay is very sticky and is quite different in appearance from the common Miocene clay. It is similar in appearance to that exposed at Blue Banks Landing on the Tar River.

RAVINE ALONG ROAD, 1 MILE WEST OF GREENVILLE.

	Feet.
Pleistocene (?):	
Concealed	3
Miocene (St. Marys):	
Stratified interlaminated light drab and gray sand, stained with iron in places	8
Dark blue clay with thin partings of gray to blue sand, with some comminuted vegetable matter in the sand	7

Three Miles West of Greenville, West Side of Harris Mill Run.—Marl has been dug at this point and is similar to the other marl of this vicinity. Numerous sharks' teeth were found at the pit.

FOSSILS FROM 3 MILES WEST OF GREENVILLE.

GASTROPODA:
Polynices heros Say.
Turritella variabilis Conrad.
SCAPHOPODA:
Dentalium attenuatum Conrad.
PELECYPODA:
Anomia simplex d'Orbigny.
Astarte concentrica Conrad.
Astarte symmetrica Conrad.
Cardium laqueatum Conrad.
Crassatellites undulatus Say.
Glycymeris suborata Say.
Glycymeris americana de France.
Mulinia congesta Conrad.
Ostrea compressirostra Say.
Ostrea sculpturata Conrad.
Pecten jeffersonius Say.
Venericardia granulata Say.
Venus tridacnoides Lamarck.

Two Miles West of Greenville, Along East Side of School House Branch.—At this place there is a series of old marl pits from which great quantities of marl have been taken in the past, and one pit has been worked recently. The material consists of gray to yellow argillaceous sand, containing great quantities of perfectly preserved shells, bones, and some phosphatic pebbles.

FOSSILS FROM 2 MILES WEST OF GREENVILLE.

GASTROPODA:
Lirosoma sulcosa Conrad.
Turritella variabilis Conrad.

PELECYPODA:
Astarte symmetrica Conrad.
Crassatellites undulatus Say.
Glycymeris americana de France.
Glycymeris subovata Say.
Mulinia congesta Conrad.
Ostrea compressirostra Say.
Ostrea sculpturata Conrad.
Pecten madisonius Say.
Pecten eboreus Conrad.
Pecten jeffersonius Say.
Phacoides anodonta Say.
Plicatula marginata Say.
Venericardia granulata Say.
Venus campechiensis Conrad.
Venus rileyi Conrad.
Phacoides crenulatus Conrad.
Phacoides trisulcatus Conrad.

The St. Marys Miocene outcrops along the Tar River about ¾ mile above Greenville, where it consists of light gray, rather compact sand, containing poor fossil casts.

RIGHT BANK OF TAR RIVER, AT GREENVILLE, JUST BELOW BRIDGE.

	Feet.
Pleistocene:	
Brown to buff, coarse, stratified and cross-bedded sand, largely concealed by vegetation	12
Pebble band, pebbles of quartz and white Miocene clay in matrix of gray sand	3
Miocene (St. Marys):	
Fine, somewhat sandy white diatomaceous (?) clay, containing a few small quartz pebbles and filled with fossil impressions	4
Shell bed, shells rather fragile in matrix of ferruginous brown sand	3½
Gray to buff to yellow, fine to medium coarse sand, containing many fossil impressions in places and in one place a small lens of shells. There is a little glauconite present. Exposed to water's edge, low water	15

FOSSILS FROM TAR RIVER AT GREENVILLE.

GASTROPODA:
Cadulus thallus Conrad.
Calliostoma philanthropus Conrad.
Crepidula aculeata Gmelin var. *costata* Morton.
Crepidula fornicata Say.
Crepidula plana Say.
Fissuridea redimicula Say.
Marginella limatula Conrad.
Aurinia mutabilis Conrad.
Teinostoma nanum H. C. Lea.
Turbonilla reticulata C. B. Adams.
Turritella variabilis Conrad.
Vermetus sculpturatus H. C. Lea.

SCAPHOPODA:
Dentalium attenuatum Say.

PELECYPODA:
Aligena aequata Conrad.
Anomia aculeata Gmelin.
Anomia simplex d'Orbigny.
Asaphis centenaria Conrad.
Astarte concentrica Conrad.
Astarte symmetrica Conrad.
Astarte undulata Say.
Calocardia sayana Conrad.
Cardium laqueatum Conrad.
Cardium sp.
Corbula inaequalis Say.
Crassatellites undulatus Say.
Dosinia acetabulum Conrad.
Ensis directus Conrad.
Glycymeris americana de France.

Glycymeris subovata Say.
Leda acuta Conrad.
Macrocallista albaria Say.
Modiolus ducatelii Conrad.
Mulinia congesta Conrad.
Nucula proxima Say.
Nucula taphria Dall.
Ostrea compressirostra Say.
Ostrea sculpturata Say.
Pandora crassidens Conrad.
Panopea reflexa Say.
Pecten decemnarius Conrad.
Pecten eboreus Conrad.
Pecten jeffersonius Say.
Pecten madisonius Say.
Pecten jeffersonius var. *edgcombensis* Conrad.
Pecten jeffersonius var. *septenarius* Say.
Phacoides anodonta Say.
Phacoides crenulatus Conrad.
Phacoides trisulcatus Conrad.
Plicatula marginata Say.
Rangia clathrodonta Conrad.
Semele subovata Say.
Venericardia granulata Say.
Venus campechiensis Conrad.
Venus rileyi Conrad.
Venus tridacnoides Lamarck.
Yoldia laevis Say.

Four Miles Southeast of Greenville on Hardee Creek.—Compact bluish-gray sand filled with fossil shells, *Mulinia congesta* especially abundant. Some coral and water-worn sharks' teeth have been dug at this point for fertilizing purposes. The marl pits are filled with water so that the marl was not observed in place.

Nine to Ten Miles South of Greenville on New Bern Road.—Marl has been dug at several places in this vicinity. The marl consists of a bluish-gray argillaceous sand filled with fossil shells and some black phosphatic pebbles. It lies about 8 feet beneath the surface.

Marl Pit About 1 1-2 Miles West of Galloway Cross Roads, and 8 or 9 Miles Southeast of Greenville.—Marl has been dug in considerable quantities on Juniper Branch, 1/4 mile to east of main road. It consists largely of calcareous clay, but there are shells in the upper part. The matrix is calcareous sand. The marl is struck at about 4 feet from the surface.

Two-thirds Mile North of Galloway Cross Roads.—The marl stratum has furnished marl for fertilizing purposes at this point.

One-half Mile Below Cherry Landing, Tar River, 6 Miles Below Greenville.—Section well exposed for several hundred yards along right bank.

	Feet.
Pleistocene:	
White loose sand	3-6
Miocene (St. Marys):	
Dark greenish-gray sandy clay with ferruginous streaks at top	6
Greenish-gray argillaceous clay full of fossils	8
Similar to above, but less sandy and becoming hard and slippery at base, being without sand content and containing fewer fossils.	6½

The horizon represented here is the same as at Taft's Landing.

TAFT'S LANDING, TAR RIVER, 6¾ MILES BELOW GREENVILLE, RIGHT BANK.

Pleistocene:	FEET.
Gray sand, ferruginous at base	7
Miocene (St. Marys):	
Dark greenish-gray arenaceous clay with thin laminæ of fine sand, iron-stained in places, with some fossils and casts near base. Dark green or greenish-gray sandy clay full of shells at top with fewer shells at base	6

Marl Pits 1-2 Mile North of Grimesland on Tributary of Chilcod Creek.—Marl has been dug here within a few years and seems to be the same formation as that about Greenville, Tarboro, and Rocky Mount. The marl is very different, lithologically, from that near Chocowinity, though so few fossils could be found that it is difficult to say how unlike it is paleontologically. The shells are found in a blue sand matrix, and fragments of shells seem to be wanting. The owner of the pit reports that in this same vicinity the fragmental marl—red marl—occurs, so that it seems that the Yorktown and St. Marys formations occur here.

SECTIONS ALONG CONTENTNEA CREEK AND ITS TRIBUTARIES.

Record of County Well at Wilson, N. C., located on Courthouse Square.

Pleistocene:	FEET.
Fine yellow argillaceous sand at depth of	1-10
Fine yellow, slightly argillaceous sand	10-20
Mottled pink and white finely arenaceous clay	20-30
Miocene (St. Marys):	
Bluish drab clay	30-50
Greenish-gray sandy clay, with a few shell fragments as follows: *Mulinia* sp. (?), *Pecten* sp., *Phacoides crenulatus*	50-55
Marine shells more or less fragmentary, with an admixture of coarse quartz sand and angular pieces of quartz, and pieces of crystalline rock up to ½ inch in diameter. The following forms were recognized: *Arca* sp., *Balanus concavus, Cadulus thallus, Crepidula aculeata, Crepidula fornicata, Echinoid spines, Ensis* sp., *Mulinia congesta, Ostrea sculpturata, Phacoides crenulatus, Venus rileyi, Yoldia laevis*	55-60
Shells more or less fragmentary, with some admixture of coarse angular quartz sand and angular pieces of quartz up to ½ inch in diameter. The following forms were recognized: *Arca* sp. (?), *Mulinia congesta, Pecten eboreus, Venus* sp.	60-65
Greenish-gray calcareous clay	65-75
Pre-Cambrian:	
Crystalline rock, considerably decomposed in upper portion, less so in the lower levels	80-113

On Toisnot Creek, about ¾ mile north of Wilson, N. C., marl was formerly dug. The old marl pit was filled with water. The marl could not be seen in place.

On Hominy Creek, just west of Wilson, old marl pits were found, but no marl was exposed because of the water which fills them. Some specimens of fossils from the marl are found about the pit.

MARL PIT NEAR WILSON.

GASTROPODA:
- *Crepidula fornicata* Say.
- *Crepidula plana* Say.
- *Marginella limatula* Conrad.
- *Polynices duplicatus* Say.
- *Seila adamsi* H. C. Lea.
- *Teinostoma nanum* H. C. Lea.
- *Teinostoma undula* Dall.
- *Tornatina canaliculata* Say.
- *Turbonilla interrupta* Totten.
- *Turbonilla reticulata* C. B. Adams.
- *Turritella variabilis* Conrad.

PELECYPODA:
- *Abra aequalis* Say.
- *Aligena aequata* Conrad.
- *Anomia aculeata* Gmelin.
- *Anomia simplex* d'Orbigny.
- *Arca improcera* Conrad.
- *Arca limula* Conrad.
- *Astarte concentrica* Conrad.
- *Cardium* sp.
- *Crassatellites lunulatus* Conrad.
- *Crassatellites undulatus* Say.
- *Cumingia medialis* Conrad.
- *Diplodonta acclinis* Conrad.
- *Divaricella quadrisulcata* d'Orbigny.
- *Ensis directus* Conrad.
- *Gafrarium metastriatum* Conrad.
- *Gemma magna* Dall.
- *Gemma trigona* Dall.
- *Leda acuta* Conrad.
- *Modiolus ducatelii* Conrad.
- *Mulinia congesta* Conrad.
- *Nucula proxima* Say.
- *Ostrea sculpturata* Conrad.
- *Pecten eboreus* Conrad.
- *Phacoides crenulatus* Conrad.
- *Plicatula marginata* Say.
- *Tellina declivis* Conrad.
- *Venericardia granulata* Say.
- *Venus rileyi* Conrad.
- *Yoldia laevis* Say.

Marl Pits of Jack Batchelor, 2 Miles Southeast of Sharpsburg.— Several old pits occur here, but no marl has been dug for 20 years at least. A few fossils collected. *Mulinia congesta* makes up almost entire marl.

Seven Miles Southeast of Wilson, East Side of White Oak Swamp.— At this place a bed of marl lies from 5 to 7 feet beneath the surface. The overlying Pleistocene material consists of loose laminated sand, while the Miocene fossil shells and bones are contained in a matrix of argillaceous bluish drab sand.

CONTENTNEA CREEK, ½ MILE ABOVE SPEIGHTS BRIDGE.

	Feet.
Pleistocene:	
Concealed by vegetation	12
Sand poorly exposed, with gravel band at base	12-15
Miocene (St. Marys?):	
Laminated dark brown loamy clay, containing some fine comminuted vegetable matter	3
Light yellow, iron-stained sand, containing a small amount of lignite	6

Cretaceous (Patuxent):	FEET.
Compact drab sandy micaceous clay	4
Compact micaceous arkosic sand	6

At Speights Bridge, Contentnea Creek, the St. Marys Miocene is exposed. It consists of a calcareous sandstone containing numerous fossil casts, *Mulinia congesta* being the most abundant.

Miocene strata are exposed along Contentnea Creek in the vicinity of Snow Hill in many places, though definite information in regard to them is lacking.

ONE MILE NORTH OF CASTORIA, MARL PITS ON PROPERTY OF A. R. HINSON.

Pleistocene:	FEET.
Black loose sandy silt loam	3
Gray and brown sand	3
Miocene (St. Marys):	
Dense blue micaceous, argillaceous sand, with little acicular quartz crystals between the laminæ	2
Shell marl, matrix a bluish drab, rather sticky clay, somewhat sandy in certain places. Shells well preserved and very numerous	7

ONE MILE EAST OF LIZZIE, ON JIM BRANCH.

Pleistocene:	FEET.
Drab plastic clay loam, weathering yellow	2
Miocene (St. Marys):	
Bluish-drab laminated sandy clay	3-4
Marl bed composed of loose sand, containing considerable argillaceous matter in places and numerous fossils, consisting principally of molluscan remains, though some Echinoid spines, sharks' teeth and bones are present. It also contains a few black phosphatic pebbles	15

Four Miles East of Lizzie, Greene County.—Marl has been dug in this vicinity in a great many places in the past. The matrix consists of a gray, argillaceous sand, containing numerous small Pelecypods, some sharks' teeth, and occasional phosphate pebbles and vertebrate bones. The marl does not outcrop, but lies about 5 feet below the flood plain of the stream. It is said to vary in thickness from 7 to 10 feet. The fossils found here are both varied and plentiful.

One-half Mile West of Lizzie, Greene County.—Marl has been dug on the lowlands in this vicinity and consists of a gray calcareous sand filled with small Pelecypod shells and containing a few phosphatic pebbles.

Marl Pits on Jacob Branch, 2 Miles Southeast of Tugwell, Pitt County.—There are a number of marl pits at this place, two of which

have been worked recently and have piles of marl about them. The marl is similar to that along Pine Log Branch, except for the predominance of *Glycymeris* and *Venericardia granulata.*

Black Swamp, 2 Miles North of Farmville.—There are a number of old water-filled marl pits here, but no fossils could be found.

All along the Little Contentnea Creek and its tributaries marl occurs and has been dug in the past. The marl does not outcrop, but is reached by digging in the flood plain to a depth of 5 to 10 feet. Sometimes the water interferes with digging, as the marl is below the level of the water in the streams. The pits fill with water as soon as digging ceases and fish get into these holes when the streams overflow. These old marl pits are better for fishing than are the streams, and can usually be located by paths leading to them, made by the fishermen.

One-half Mile East of Ormondsville.—Some shells found about old marl pits in this vicinity indicate that the marl underlies practically this whole region between Contentnea Creek and the Tar River.

Two and One-third Miles North of Standard, Pitt County.—Characteristic St. Marys marl occurs along a small stream and many marl pits are present in this vicinity. Some of the marl seems to have been rather firmly indurated.

Plantation of J. A. Nobles Along a Branch 1 Mile South of Road Leading from Frog Level to Standard, Pitt County.—There is a long series of old pits here. Marl lies but a few feet from the surface. The matrix is a blue-gray sand which weathers to iron-red colors. The larger shells were almost all broken.

Three Miles North of Grifton, Pitt County.—Numerous marl pits in this vicinity indicate that the St. Marys Miocene is well developed in this vicinity. In some places the marl seems to consist almost entirely of shells with very little sand matrix.

Old Woman Branch, Pitt County.—Marl pits are said to be numerous along this branch, though none of them have been worked for a number of years.

TWO MILES EAST OF GRIFTON, PITT COUNTY.

	Feet.
Pleistocene:	
Loose black silt loam	½-1
Loose, coarse, gray to brown sand, iron-stained in places	2-3
Miocene (St. Marys):	
Shell bed, fossil shells contained in a matrix of argillaceous blue to drab sand, cemented by iron in some places. Most of the shells are fragmentary, though some are entire	0-5
Blue sandy marl, containing a few fossils	12

This lower member has not been cut through. It may be considerably thicker than 12 feet.

One and One-fourth Miles West of Walters, Wayne County.—Miocene marl was dug at this place a few years ago. The fossil shells represent a large variety of species and are contained in a matrix of bluish-gray argillaceous sand.

YORKTOWN FORMATION.

Name.—The Yorktown formation receives its name from Yorktown, Virginia, where beds of this age are well developed and from whence many excellent fossils have been obtained. The name "Yorktown" was applied to all the Miocene and Pliocene strata of the Atlantic Coastal Plain by James D. Dana in 1863, but not until 1906 was the formation definitely described by Clark and Miller (Va. Geol. Surv. Bull., No. II, pp. 19-20, Richmond, Va., 1906). The formation has not been represented as extending south of Virginia in any publications that have thus far appeared, but in the collection of material for this chapter it has been found that the formation with few changes does extend from Virginia southward into the State of North Carolina.

The beds in North Carolina that are now referred to the Yorktown formation have usually been considered a part of the undifferentiated Miocene, though the same strata were referred by Heilprin to the "Carolinian division" of the Miocene.

Definition.—The Yorktown formation comprises the latest Miocene strata of northern North Carolina and, with the Duplin formation, which is probably in part contemporaneous, constitute the uppermost divisions of the Miocene of the Atlantic Coastal Plain. In Virginia two Miocene formations are found beneath the St. Marys and the Yorktown, but these have as yet not been recognized in North Carolina, and it seems that they are entirely absent. The Yorktown rests directly upon the St. Marys, with which it is unconformable.

This formation extends in discontinuous patches across the northeastern part of the State, being especially well represented along the Chowan, Lower Roanoke, Lower Tar, and Lower Neuse rivers and their tributaries. Other isolated patches of small areal extent are found in intervening regions.

As stated above, the Yorktown formation rests upon the St. Marys strata wherever these are developed, but in their absence it is found in immediate contact with the underlying Eocene or Cretaceous. Along Wiccacon Creek and the Chowan River it rests upon St. Marys strata, and the same is true of the deposits found near Washington on the Tar River. Along the Lower Neuse River in the vicinity of New Bern the St. Marys formation is wanting, and there the Yorktown rests directly upon the Trent formation. This is well exhibited at Rock Landing on

the Neuse River, about 16½ miles above New Bern. At that point the Trent is well exposed along the river bank overlain by a thin layer of Pleistocene, while a few rods away, along a small tributary stream, the Yorktown Miocene is well developed and shows its usual lithologic characteristics.

The Yorktown formation is overlain by Pleistocene deposits wherever sections have been exposed to view, but there are, no doubt, beneath the Pleistocene covering, many places where the Pliocene beds are in immediate contact with the Yorktown strata.

In North Carolina the Yorktown is unconformable with all the strata with which it is in contact, both the older and the younger formations. On this basis alone it could be separated from all of the other formations of the State. Its lithologic and paleontologic characters, however, are also diagnostic.

The Yorktown strata were deposited in marine waters that were mainly of very shallow depth. The formation consists principally of sands and shell marls with slight admixtures of clay and occasional clay laminæ. The marl beds can usually be distinguished from the marl beds of the St. Marys formation by the presence of large quantities of shell fragments. These fragmentary shell beds are best developed at Yorktown, Virginia, though they are also seen in a number of places in North Carolina, particularly at Tar Ferry on Wiccacon Creek in Hertford County and at Rock Landing on the Neuse River in Craven County. In certain places these fragmentary shell deposits closely resemble the beach materials present on some of the coral islands of the West Indies. Associated with these fragmentary shells are many more or less perfect shells, some of which show evidence of having been worn by the water, while in others there is no indication of their having been moved after the death of the animal. Some of the most perfect fossils are the shells of boring *Mollusca* that had evidently buried themselves in the bottom of the shallow water. Specimens of *Panopea* are found upright in these deposits in a perfect state of preservation. The shell marls of the Yorktown formation are usually loose, though occasionally they have been cemented by percolating waters and form a rather firm fragmental limestone not unlike coquina rock. The marls of the Yorktown formation are rich in lime and have been quarried for fertilizing purposes in a number of localities throughout the State. Old marl pits in this formation are numerous in Hertford, Martin, Beaufort, and Craven counties.

Besides the marl deposits, the Yorktown formation contains much sand that is usually light colored and fine grained. In some localities the sand when fresh is bluish-gray in color, but on weathering loses its original color and becomes light gray to buff.

The detailed sections that are given on later pages furnish examples of the different materials that constitute the Yorktown formation.

Thickness.—The Yorktown formation is of variable thickness, depending somewhat upon the amount of erosion which it has suffered since its deposition. In Hertford, Bertie, Martin, Beaufort, and Craven counties it is rather thin, probably never more than 50 feet in thickness. It may thicken to the eastward, as the Coastal Plain formations so frequently do, though we have no evidence that such is the case in regard to this formation.

The different areas of the Yorktown formation may perhaps represent somewhat different horizons, in which case the total thickness may be somewhat greater. Until the paleontologic investigations have been carried farther it will not be possible to determine this point.

The great beds of shell marl that form such an important part of the Yorktown formation have yielded a great variety of fossils.

Lists of fossils from different localities are given in the detailed sections on a later page and show the rich fauna obtained from the Yorktown formation in this State. Beside the forms that have been determined, there are many other new species from almost every locality from whence collections have been made that have as yet not been described. When the fauna of the Yorktown formation is completely described it will probably be found to be one of the richest faunas in numbers of species represented in this country. The fossils from Yorktown, Va., have been more carefully studied up to the present time than those from any locality in the Yorktown formation in North Carolina, and for that reason the list of species identified by Dr. Dall from that locality is given.

FOSSILS FROM YORKTOWN, VA.

GASTROPODA:

Anachis harrisii Dall.
Calliostoma sp.
Calliostoma briani Conrad.
Calliostoma distans Conrad.
Calliostoma harrisii Dall.
Calliostoma mitchelli Conrad.
Calliostoma ruffini H. C. Lea.
Calliostoma philanthropus var. *basicum* Dall.
Calliostoma philanthropus Conrad vars.
Calliostoma virginicum Conrad.
Caecum stevensoni Meyer.
Caecum virginianum Meyer.
Clathurella sp.
Conus diluvianus Green.
Crepidula aculeata Gmelin var. *costata* Morton.
Crepidula fornicata Say.
Crepidula plana Say.
Creseis recta Blainville.
Crucibulum ramosum Conrad.
Drillia sp.
Drillia sp.
Drillia eburnea Conrad.
Drillia tricatenaria Conrad.
Ecphora quadricostata Say.
Fissurella sp.
Fissurella marylandica (Conrad).
Fissurella redimicula (Say).
Ilyanassa granifera Conrad.

Ilyanassa isogramma Dall.
Ilyanassa? (Paranassa) porcina (Say).
Litorina irrorata (Say).
Marginella bella Conrad.
Marginella limatula Conrad.
Nassa (Paranassa) harpuloides Conrad.
Peristernia filicata Conrad.
Pleurotoma limatula Conrad.
Polynices (Neverita) duplicatus (Say).
Ptychosalpinx altilis Conrad.
Ptychosalpinx laqueatum Conrad.
Ptychosalpinx tuomeyi H. C. Lea.
Scala sp.
Solarium nuperum Conrad.
Turritella alticostata Conrad.
Urosalpinx trossulus Conrad.

SCAPHOPODA:
Cadulus thallus Conrad.
Dentalium attenuatum Say.

PELECYPODA:
Abra subreflexa Conrad.
Anomia aculeata Linné.
Arca carolinensis Wagner.
Arca (Barbatia) centenaria Say.
Arca (Noëtia) incile Say.
Arca lienosa Say.
Arca staminea Say.
Astarte concentrica Conrad.
Astarte exaltata Conrad.
Astarte obruta Conrad.
Bornia sp.
Bornia triangula (H. C. Lea).
Callocardia subnasuta Conrad.
Callocardia sayana Conrad.
Cardita (Carditamera) arata Conrad.
Cardium taenopleura Dall.
Chama congregata Conrad.
Chama corticosa Conrad.
Chione latilirata Conrad.
Corbula sp.
Corbula inaequalis Say.
Crassatellites sp.
Crassatellites undulata Say.
Crassatellites (Crassinella) galvestonensis Harris.
Crassatellites (Crassinella) lunulatus Conrad.
Cumingia medialis Conrad.
Diplodonta acclinis Conrad.
Diplodonta nucleiformis Wagner.
Diplodonta yorkensis Dall.
Divaricella quadrisulcata d'Orbigny.
Dosinia acetabulum Conrad.
Ensis magna var. *virginiana* Dall.
Glycymeris americana de France.
Glycymeris subovata Say.
Isocardia fraterna Say.
Leda acuta Conrad.
Macoma conradi Dall.
Macoma virginiana Conrad.
Macrocallista albaria Say.
Modiola ducatelli Conrad.
Modiolaria virginica Conrad.
Montacuta sagrinata Dall.
Mya arenaria Linné.
Mulinea congesta Conrad.
Nucula proxima Say.
Ostrea sculpturata Conrad.
Pandora arenosa Conrad.
Panopea reflexa Say.
Pecten decemnarius Conrad.
Pecten eboreus Conrad var. *yorkensis* Conrad.
Pecten edgecombensis Conrad.
Pecten jeffersonius Say.
Pecten madisonius Say var.
Petricola (Rupellaria) harrisii Dall.
Phacoides (Pseudomiltha) anodonta Say.
Phacoides (Parvilucina) crenulata Conrad.
Phacoides (Lucinisca) cribrarius Say.
Racta alta Conrad.
Rangia clathrodonta Conrad.
Rochefortia sp.
Semele nuculoides Conrad.
Semele subovata Say.
Sphenia dubia H. C. Lea.
Spisula delumbis Conrad.
Spisula modicella Conrad.
Spisula subparilis Conrad.
Sportella yorkensis Dall.
Tagelus gibbus Spengler.
Tellina (Merisca) aequistriata Say.

Tellina (*Angulus*) *dupliniana* Dall.
Tellina (*Angulus*) *declivis* Conrad.
Tellina (*Angulus*) sp.
Tellina (*Angulus*) *propetenella* Dall.
Thracia transversa H. C. Lea.
Venericardia (*Cyclocardia*) *granulata* Say.
Venericardia (*Pleromeris*) *perplana* Conrad.
Venus (*Tridacnoides*) *deformis* Say.
Venus (*Tridacnoides*) *rileyi* Conrad.
Venus plena Conrad.
Venus plena Conrad var. *inflata* Dall.
Venus plena Conrad var. *nucca* Dall.
Yoldia laevis Say.
Yoldia laevis? Say.

The Yorktown formation stretches in a belt across the State from northeast to southwest as far as the Neuse River. It seems to be practically continuous beneath the Pleistocene cover from the Dismal Swamp in Gates County southward through Hertford, Chowan, Bertie, Washington, Martin, Beaufort, Pitt, and Craven counties to the Neuse River. South of the Neuse River it has not been recognized.

The Yorktown formation locally has dips of 5 to 10 degrees, but these are unusual. So far as instrumental observations can determine the inclination of the beds, the formation is practically horizontal. Occupying depressions in the irregular surface of the older formations, the basal beds may dip with the slope of the depressions, but the upper beds are practically level. It probably everywhere has a general dip of a few feet to the mile toward the ocean.

Detailed Sections.

TAR FERRY, WICCACON CREEK, HERTFORD COUNTY.

	FEET.
Pleistocene:	
Yellowish-brown clay loam	13
Miocene (Yorktown):	
Fine gray sand	4
Marl layer, perfectly preserved shells in matrix of broken shells and sand. Sand is blue when unweathered, yellow where exposed. This material seems to extend to water, though exposures are poor at base, and some of it may have slipped down from above	20

FOSSILS FROM TAR FERRY, WICCACON CREEK.

GASTROPODA:
Crepidula fornicata Say.
Dentalium attenuatum Say.
Marginella contracta Conrad.
Marginella denticulata Conrad.
Marginella limatula Conrad.
Olivella mutica Say.
Polynices duplicatus Say.
Scalaspira strumosa Conrad.
Seila adamsi H. C. Lea.
Teinostoma nanum H. C. Lea.
Tornatina canaliculata Say.
Triforis perversa Linné var. *nigrocincta* Adams.
Turbonilla interrupta Totten.
Turritella variabilis Conrad.
Vermetus graniferus Say.
Vermetus sculpturatus H. C. Lea.

PELECYPODA:
Abra aequalis Say.
Arca limula Conrad.
Astarte concentrica Conrad.

Astarte undulata Say.
Bornia triangula Dall.
Callocardia sayana Conrad.
Cardita arata Conrad.
Corbula cuneata Say.
Corbula inaequalis Say.
Crassatellites lunulatus Conrad.
Crassatellites undulatus Say.
Cumingia medialis Conrad.
Diplodonta acclinis Conrad.
Diplodonta leana Dall.
Ensis directus Conrad.
Gafrarium metastriatum Conrad.
Gemma magna Dall.
Gemma trigona Dall.
Glycymeris americana de France.
Glycymeris subovata Say.
Leda acuta Conrad.
Macrocallista albaria Say.
Modiolus ducatelii Conrad.
Montacuta petropolitana Dall.
Mulinia congesta Conrad.
Mulinia lateralis Say.
Nucula proxima Say.
Ostrea compressirostra Say.
Pandora crassidens Conrad.
Pecten eboreus Conrad.
Phacoides anodonta Say.
Phacoides crenulatus Conrad.
Plicatula marginata Say.
Sportella constricta Conrad.
Sportella protexta Conrad.
Tellina declivis Conrad.
Tellina dupliniana Dall.
Venericardia granulata Say.
Venericardia perplana Conrad.
Venericardia tridentata Say.
Venus rileyi Conrad.
Yoldia laevis Say.

Along the Chowan River there are many exposures of the Yorktown formation. At Colerain Landing the river bluff, which is here from 45 to 50 feet in height, consists of light yellow argillaceous sands and sandy clays, with some laminated layers of drab clay. The material becomes more sandy in lower portion, grading into a yellow sand at base. The lower half is more or less fossiliferous. At about 25 feet above the base there is a lens of shells, about 2½ feet thick in the middle and tapering at the ends. The lens is 75 feet to 100 feet long. At the base, at water's edge, there is a layer of shells 2 feet thick, the most conspicuous form being *Glycymeris*.

Between Colerain and Mount Gould landings there are a number of 50-foot bluffs in which the Miocene exposed consists of light yellow sands and clays that show stratification. About ¾ mile above Mount Gould Landing, the base of the bluff, up to about 10 feet, is made up of dark green sandy clay filled with fossil shells which are for the most part very fragile and poorly preserved. This bed appears to be a lens in lighter colored sands and clays.

Between Jernigen's Wharf and Edenhouse Point the bluffs do not exceed 25 to 30 feet. One mile above Edenhouse Point a fossiliferous bed occurs in the lower 8 feet of the bluff. In this exposure branching corals are particularly abundant. The marl pits do not have very great lateral extent and seem to be small lenses in the quartz sands. The stratification seems to indicate that the beds are practically horizontal. The same layer is exposed at intervals all the way from Tar

Ferry on Wiccacon Creek to Mount Pleasant Landing on the Chowan River. Also, some other beds in the same vicinity can be traced at almost exactly the same level for a distance of 2 or 3 miles.

FOSSILS FROM CHOWAN RIVER LOCALITIES.

GASTROPODA:
- *Crepidula aculeata* Gmelin var. *costata* Morton.
- *Crepidula fornicata* Say.
- *Crepidula plana* Say.
- *Crucibulum constrictum* Conrad.
- *Dentalium attenuatum* Say.
- *Marginella limatula* Conrad.
- *Polynices duplicatus* Say.
- *Scalaspira strumosa* Conrad.
- *Aurenia mutabilis* Conrad.
- *Turritella variabilis* Conrad.
- *Vermetus graniferus* Say.

PELECYPODA:
- *Abra aequalis* Say.
- *Aligena aequata* Conrad.
- *Arca limula* Conrad.
- *Astarte concentrica* Conrad.
- *Astarte undulata* Say.
- *Callocardia sayana* Conrad.
- *Cardita arata* Conrad.
- *Cardium sublineatum* Conrad.
- *Chione cribraria* Conrad.
- *Corbula inaequalis* Say.
- *Crassatellites undulatus* Say.
- *Cumingia medialis* Conrad.
- *Diplodonta acclinis* Conrad.
- *Ensis directus* Conrad.
- *Gemma magna* Dall.
- *Glycymeris americana* de France.
- *Glycymeris subovata* Say.
- *Leda acuta* Conrad.
- *Modiolus ducatelii* Conrad.
- *Mulinia congesta* Conrad.
- *Nucula proxima* Say.
- *Ostrea sculpturata* Conrad.
- *Panopea reflexa* Say.
- *Pecten eboreus* Conrad.
- *Phacoides anodonta* Say.
- *Phacoides crenulatus* Conrad.
- *Phacoides contractus* Say.
- *Pholas producta* Conrad.
- *Plicatula marginata* Say.
- *Venericardia granulata* Say.
- *Venus rileyi* Conrad.

Marl Pit 1 Mile Northeast of Chocowinity.—Marl has been dug just at the foot of the bluff which borders the river flood plain. Were it not for the slump of the bank the shell stratum would outcrop. The marl consists of many perfect shells in a matrix of fragmental shells and sandy clay. It is not possible to determine the thickness of the marl.

Rock Landing, Neuse River, 16 1-2 Miles Above New Bern.—On the river bank at this place there is a good exposure of Eocene, which section has been given in a previous page. The unconformity between the Eocene and the overlying Miocene is well exposed at this place, as the Eocene at the river bank rises about 10 feet above the water, while a few hundred rods above the Miocene extends down to about the level of the river. In this latter locality no Eocene is exposed, but instead there is a thickness of about 8 feet of Miocene materials which consist primarily of fragmentary shells in which are numerous specimens in a good state of preservation. Some siliceous sand grains are present, but the sand does not form any considerable part of the deposit. The

marl is quite firmly cemented in some places, particularly near the exposed surface, but in other places it is very loose and crumbles readily when struck with a hammer. The variety of species collected at this point is large, as is shown by the following list.

FOSSILS FROM ROCK LANDING, NEUSE RIVER.

GASTROPODA:
Cadulus thallus Conrad.
Caecum carolinianum Dall.
Caecum cooperi S. Smith.
Caecum floridanum Stimpson.
Conus marylandicus Green.
Crepidula fornicata Say.
Crepidula plana Say.
Cyprea carolinensis Conrad.
Dentalium attenuatum Say.
Marginella aureocincta Stearns.
Marginella limatula Conrad.
Oliva litterata Lamarck.
Polynices duplicatus Say.
Polynices heros Say.
Tornatina canaliculata Say.
Turritella variabilis Conrad.
Vermetus sculpturatus H. C. Lea.
Vermetus virginica Conrad.

PELECYPODA:
Anomia simplex d'Orbigny.
Arca improcera Conrad.
Arca limula Conrad.
Astarte concentrica Conrad.
Astarte undulata Say.
Cardita arata Conrad.
Cardium sp.
Chama congregata Conrad.
Chione latilirata Conrad.
Corbula inaequalis Say.
Crassatellites lunulatus Conrad.
Crassatellites undulatus Say.
Diplodonta acclinis Conrad.
Gafrarium metastriatum Conrad.
Gemma magna Dall.
Gemma trigona Dall.
Glycymeris americana de France.
Glycymeris pectinata Gmelin.
Glycymeris subovata Say.
Leda acuta Conrad.
Mulinia congesta Conrad.
Nucula proxima Say.
Ostrea compressirostra Say.
Ostrea sculpturata Conrad.
Pecten eboreus Conrad.
Pecten mortoni Ravenel.
Phacoides anodonta Say.
Phacoides Say.
Phacoides trisulcatus Conrad.
Plicatula marginata Say.
Venericardia granulata Say.
Venericardia perplana Conrad.
Venericardia tridentata Say.

Two Miles Southwest of Maple Cypress, Craven County.—Miocene shell marl is poorly exposed. Some of it was seen about old marl pits. Shells are almost entirely fragmentary, but a few perfect specimens obtained. Resembles the Rock Landing Miocene.

Similar marl has been dug in many places along Core Creek.

DUPLIN FORMATION.

Name.—A specific account of the geology of the vicinity of Natural Well, Duplin County, appears in Dall and Harris' Neocene Correlation Paper,[1] but the formation is not named there. In the Proceedings of the United States National Museum, vol. 18, 1895, page 40, occur the two following references: referring to *Terebra neglecta* Emmons, Dall

[1] U. S. Geological Survey Bulletin 84, pages 72-73, 1892.

says: "It was described by Emmons from the Miocene of North Carolina, but was not found by Burns in the Duplin beds;" referring to *Terebra dislocata* var. *indenta* Conrad. "*Habitat.*—Duplin beds at the Natural Well, Duplin County, North Carolina." This is the first use of the name Duplin beds, but they were not there specifically defined. However, in the Eighteenth Annual Report of the U. S. Geological Survey, Part II, 1898, in Dall's article, "A Table of the North American Tertiary Horizons, Correlated With One Another and With Those of Europe, With Annotations," pages 327-348, the formation is definitely named. On page 338 Dall states, "*Duplin beds.*—Late Miocene marls of Duplin County, North Carolina," and gives a reference to Conrad, American Journal of Science, 1st ser., vol. 12, pp. 335-343. In the Correlation Table "Duplin beds" occurs in the column headed Atlantic States. Dall, in his Tertiary Fauna of Florida, Wagner Free Institute of Science, vol. 3, part VI, 1903, pp. 1598-1603, gives a further account of the Duplin beds and a detailed list of the fauna obtained from the exposure in the Natural Well southwest of Magnolia. This formation has frequently been considered in the literature, and probably no Tertiary horizon is paleontologically more thoroughly known.

Definition.—The formation consists of unconsolidated sands, arenaceous clays, and shell marls representing the latest phase of Miocene deposition in the region south of the Neuse River. North of the Neuse River the Yorktown formation occupies the same stratigraphic position that the Duplin strata do in the southern part of the State, and the two formations may be in part contemporaneous. The differences in the faunas, however, render it inadvisable to include them in a single formation.

In the regions where the Duplin strata occur no other deposits of Miocene age have thus far been recognized, and wherever the basal beds are exposed the formation is seen to rest unconformably upon Cretaceous or Eocene strata.

In the vicinity of Mount Olive the Duplin formation rests upon the Trent, with which it is markedly unconformable. In the vicinity of Wilmington the Duplin beds are found immediately overlying the Castle Hayne deposits. At present the Miocene strata are not known to outcrop in Wilmington, but a few years ago, in excavating for the foundations of the Y. M. C. A. building, a deposit of Miocene marl was found overlying the Eocene limestone of the Castle Hayne formation. At the City Rock Quarries on Smith Creek Miocene marl of the Duplin formation is found in several places occupying depressions in the pitted surface of the Castle Hayne limestone. These pockets

of marl are seldom more than a foot in thickness and usually do not have a lateral extent of more than 10 or 12 feet. Beneath the Pleistocene covering of the divides, no doubt, there are places where the Duplin covers the Castle Hayne over a larger area. South of the Cape Fear River the Duplin formation seems to rest directly upon Cretaceous beds. All the evidence that has thus far been obtained seems to indicate the almost complete absence of any Eocene strata in Columbus, Bladen, and Robeson counties, and there the Miocene is found in close contact with the underlying Cretaceous beds.

In most particulars the Duplin strata are similar in lithologic characteristics to those of the Yorktown formation. Fragmental shell beds are well developed in many places and consist almost entirely of broken molluscan shells in a matrix of fine sand in which are some small water-worn pebbles and occasional perfect shells that show no effect of wave action. The deposits were evidently formed in shallow water near the shore or perhaps on the beaches where the rising and falling tides reduced the shells to fragments. At times, however, perfect shells were washed into the same places, and if soon buried by the loose débris, were preserved intact. Thus these fragmental shell layers have long been known as excellent collecting localities and have yielded great numbers of beautiful fossils in an almost perfect state of preservation.

Fine quartz sand constitutes the major portion of the Duplin strata, as in the case of the other Miocene formations. There is a considerable admixture of argillaceous material in most places. The argillaceous sand is bluish-green in color when freshly exposed, but soon changes to a buff to white color, due to the leaching of the coloring material, which consists primarily of iron carbonate.

In the Natural Well near Magnolia there is a deposit of light green argillaceous sand cemented in certain places to form a sandstone. This lies immediately beneath the shell marl and has been thought by some investigators to belong to the Eocene. Sufficient evidence for such a correlation is lacking, and it is, therefore, referred to the Duplin.

In the vicinity of Lake Waccamaw an unusual phase of the Duplin formation is developed. Outcropping along the bluff on the north shore of the lake there is a compact fossiliferous limestone that contains many casts of Molluscan shells, *Crepidula* being especially abundant. This limestone is overlain by a loose characteristic shell marl and is underlain by yellowish-brown sand that at the base contains some phosphatic pebbles and water-worn casts of Cretaceous fossils. This phase of the Duplin formation is not known to occur elsewhere in the State, though it is well developed along the Peedee River in South Carolina, particularly in the vicinity of Bostick.

In Duplin County the Duplin formation, in places, is probably nearly 100 feet thick. So far as known, the greatest thickness of the Duplin formation seems to be in Columbus County, where in a well boring near Freeman the Pliocene (?) and Miocene beds combined seem to have a total thickness of about 130 feet. A small part of this may probably represent the Pliocene that is present in this immediate vicinity, leaving perhaps little more than 100 feet as the total thickness of the Yorktown.

Specimens from the Natural Well have been studied by many investigators and are to be found in collections in many of the museums of the country. Conrad described many species from this locality and Dr. Dall, within recent years, has added many more new forms to Conrad's lists. Dr. Dall, through the study of these specimens from Duplin County, reached the conclusion that the Miocene strata of that region represent one of the last phases of deposition of the Miocene.

The list of species obtained at Natural Well, given on a later page, shows the extreme richness of the Duplin fauna. The Mollusca are especially well represented, though forms belonging to many other groups occur.

In Craven and Jones counties, between the Neuse and Trent rivers and on the south side of the Trent River, Duplin strata are found in many localities and contain marl that has been dug for fertilizing purposes. No doubt there are many other localities in the same vicinity where the formation is present, but entirely concealed from view by the overlying Pleistocene. The largest known area of the formation south of the Neuse River is that occupying a considerable part of Duplin County west of the Northeast Cape Fear River and extending westward into Sampson County, where it is found in several places in the vicinity of Clinton. In the vicinity of the Northeast Cape Fear River and its tributaries in Pender and New Hanover counties it has been observed in several places, though it does not at any place have any considerable thickness nor does it cover large areas. In Columbus County it outcrops near Whiteville and along the north shore of Lake Waccamaw and probably underlies a large part of the region to the south, though this is not known to be the case, as it does not outcrop in that region, largely due to the swampy character of the country, nor is it known to have been reached by well borings.

In Robeson County along the Lumber River and its tributaries in the vicinity of Lumberton and Fairmont, the formation is known to exist and many old marl pits show the extensive use of the marls during slavery days. In some places it is still dug, though not as extensively as in former days. The Robeson County localities may be

continuous with the strata in Columbus County and also with similar beds that occur in Marion, Florence, and Darlington counties in South Carolina, though this is rather doubtful.

South of the Neuse River, except in the vicinity of Wilmington, where thin films of the shell marl are present, erosion seems to have removed all of the easternmost portion of the formation, and likewise it has been removed along the principal river valleys that cross this region and is present only where it has escaped erosion because of its position in interstream areas.

The limited number of exposures of the Duplin formation and its occurrence in isolated areas occupying depressions in the eroded surface of underlying strata of Eocene or Cretaceous age scarcely permit the determination of the strike and dip. The local exposures seem to indicate a practically horizontal position of the beds, though it is probable that there is a gentle dip toward the east or southeast similar to the other formations of the Atlantic Coastal Plain.

Detailed Sections.

In the vicinity of Maysville many old marl pits occur, and these continue all the way to Polloksville. In these pits the Duplin Miocene shell marl has usually been quarried, but in some places the material is of Eocene age. Between Polloksville and New Bern both the Miocene marl, which here occurs in patches, and also the Eocene white limestone, which is more continuous, have been quarried for fertilizing purposes.

TWO AND ONE-HALF MILES SOUTH OF CLINTON, ON DUNCAN BRANCH.

	Feet.
Pleistocene:	
Black silt loam, chocolate brown when wet	1
Coarse sandy loam with pebbles ½ inch in diameter and ironstone nodules	2-3
Miocene (Duplin):	
Bluish drab, sticky clay	2
Shell bed, shells constituting almost entire bed in lower part	6

THREE MILES SOUTH OF CLINTON, ON GUM CHIMNEY BRANCH.

Pleistocene:	
Bluish sandy clay	1
Miocene (Duplin):	
Shell marl which is quite sandy, light brown in color	4-5
Below the marl is dark colored clay.	

Four Miles South of Clinton, N. C., Along a Branch Which Crosses Wilmington Road.—Here there is a series of pits in which a dark, chocolate-brown, loose, sandy loam with a thickness of 3 feet overlies

the Miocene marl, which has a rather coarse, loose, sandy matrix, and is iron stained. Shells are numerous. Phosphatized black pebbles as much as 1 inch in diameter occur in the marl.

SECTION AT NATURAL WELL.

Two miles southwest of Magnolia, Duplin County, is the famous Natural Well, which is so frequently referred to in geological literature of the State. This consists of a sink perhaps 75 to 100 feet in diameter and nearly circular and about 30 feet in depth. The wall on one side is quite steep, being nearly vertical, but on the other side is sloping enough to permit one to walk down to the water's edge. At the bottom of the sink there is a pond about 30 feet in diameter. (See Plate XII, B, opposite p. 250.)

The section is as follows:

	Feet.
Pleistocene:	
White loose sand, surface soil	1
Coarse yellow sand	3
White, argillaceous sand, mottled with yellow, becoming freer from clay toward base	6
Miocene (Duplin):	
White marl, contains some sand, but consists principally of very perfectly preserved shells, in a matrix of fragmental shells	3
Light green calcareous, argillaceous sand, interstratified with thin layers of calcareous sandstone, the whole being solid and compact, making a vertical wall on one side of the sink	9

Base of marl contains some water-worn pebbles, and one cobble as much as 4 inches in diameter was observed. Small pebbles occur sparingly throughout the fragmental marl.

Just to the east of the preceding, with their rims almost touching, is another similar sink. The walls are less steep, however, and the pond at the bottom is only a few feet in diameter. The strata in it are not well exposed.

Many lists of fossils obtained at the Natural Well have been published at various times. The most complete one is that given by W. H. Dall in vol. III of the Transactions of the Wagner Free Institute of Science. It is here given.

FOSSILS FROM NATURAL WELL.

GASTROPODA:
Adeorbis concavus H. C. Lea.
Adeorbis holmesii Dall.
Adeorbis leai Dall.
Adeorbis orbignyi Fischer.
Adeorbis supranitidus S. Wood.

Anachis (?) *interrupta* Conrad.
Astyris sp.
Aurinia dubia Broderip.
Aurinia mutabilis Conrad.
Aurinia obtusa Emmons.
Caecum floridanum Stimpson.

Calliostoma cyclus Dall.
Calliostoma mitchelli Conrad.
Calliostoma willcoxianum Dall.
Calyptraea centralis Conrad.
Calyptraea trochiformis Lamarck.
Cancellaria conradiana Dall.
Celatoconus nux Dall.
Cerithiopsis subulata Montague.
Chlorostoma exoletum Conrad.
Cochliopis nautiliformis Holmes.
Cochliopis striata Stimpson.
Conus adversarius Conrad.
Conus marylandicus Green.
Crepidula fornicata Say.
Crucibulum auricula var. *spinosum* Sowerly.
Crucibulum costatum Say.
Crucibulum constrictum Conrad.
Crucibulum multilineatum Conrad.
Cypraea carolinensis Dall.
Episcynia multicarinata Stimpson.
Fasciolaria acuta Emmons.
Fasciolaria elegans Emmons.
Fasciolaria gigantea Kiener.
Fasciolaria (*distans sub* sp.?) *rhomboidea* Rogers.
Fasciolaria sparrowi Emmons.
Fissuridea chipolana Dall.
Fissuridea nucula Dall.
Fossarus lyra Conrad.
Fulgur coronatum Conrad.
Fulgur maximum Conrad.
Fulgur perversum Linné.
Fulgur pyrum var. *incile* Conrad.
Fulgur pyrum var. *excavatum* Conrad.
Fulgur pyrum var. *rugosum* Conrad.
Fusus aequalis Emmons.
Gibbula americana Dall.
Ilyanassa arata Say.
Ilyanassa granifera Conrad.
Ilyanassa granifera var. *sexdentata* Conrad.
Ilyanassa (*Paranassa*) *porcina* Say.
Littorina carolinensis Conrad.
Longchaeus arenosus Conrad.
Longchaeus sp.
Macromphalina duplinensis Dall.
Marginella ovata Emmons.
Mitra carolinensis Dall.
Molleria duplinensis Dall.
Nassa bidentata Emmons.
Nassa johnsoni Dall.
Odostomia sp.
Odostomia (*Chrysallida*) sp.
Odostomia (*Egila*) sp.
Odostomia (*Evalea*) sp.
Odostomia (*Heida*) sp.
Oliva litterata Lamarck.
Olivella mutica Say.
Polynices (*Neverita*) *duplicatus* Say.
Polynices (*Lunatia*) *internus* Say.
Polynices percallusa Conrad.
Polynices perspectus Rogers.
Pseudorotella milium Dall.
Ptychosalpinx multirugata Conrad.
Scaphella trenholmi Tuomey and Holmes.
Retusa (*Cyclichnina*) *duplinensis* Dall.
Retusa (*Cyclichnina*) *microtrema* Dall.
Seonsia hodgei Dall.
Seila adamsi H. C. Lea.
Serpulorbis granifera Say.
Serpulorbis granifera var. *tenera* Dall.
Solariorbis duplinense Dall.
Solariorbis undula Dall.
Solarium granulatum Lamarck.
Terebra (*Oxymeris*) *carolinensis* Conrad.
Tereba (*Acus*) *dislocata* Say.
Terebra (*Oxymeris*) *indenta* Conrad.
Terebra (*Acus*) *protexta* Conrad.
Terebra unilineata Conrad.
Tornatina canaliculata Say.
Tornatina myrmecoön Dall.
Triforis melanura C. B. Adams.
Turbonilla (*Chemnitzia*) four sp.
Turbonilla (*Dunkeria*) sp.
Turbonilla (*Lancea*) two sp.
Turbonilla (*Pyrgiscus*) two sp.
Turbonilla (*Strioturbonilla*) three sp.
Turbonilla (*Turbonilla*) sp.
Urosalpinx trossulus Conrad.

SCAPHOPODA:

Cadulus thallus Conrad.
Dentalium attenuatum Say.
Dentalium danai Meyer var.
Dentalium disparile d'Orbigny.

PELECYPODA:

Aligena aequata Conrad.
Aligena minor Dall.
Anisodonta carolina Dall.
Anomalocardia dupliniana Dall.
Anomia simplex d'Orbigny.
Arca (Fossularca) adamsi Smith.
Arca (Scapharca) buccula Conrad.
Arca (Scapharca) carolinensis Wagner.
Arca (Barbatia) centenaria Say.
Arca (Scapharca) improcera Conrad.
Arca (Noëtia) incile Say.
Arca (Scapharca) lienosa Say.
Arca (Amusium) mortoni Ravenel.
Arca (Scapharca) plicatura Conrad.
Arca (Scapharca) scalaris Conrad.
Asaphis centenaria Conrad.
Astarte concentrica Conrad.
Astarte lyrata Conrad.
Astarte undulata Say.
Atrina harrisii Dall.
Bornia rota Dall.
Bornia triangula Dall.
Callocardia sayana Conrad.
Cardita (Carditamera) arata Conrad.
Cardium acutilaqueatum Conrad.
Cardium laqueatum Conrad.
Cardium medium Linné.
Cardium (Papyridea) semilulcata Gray.
Cardium (Laevicardium) sublineatum Conrad.
Chama congregata Conrad.
Chama striata Emmons.
Chione cribraria Conrad.
Chione (Timoclea) grus Holmes.
Chione (Lirophora) latilirata Conrad.
Codakia (Jagonia) magnoliana Dall.
Codakia (Jagonia) speciosa Rogers.
Cooperella carpenteri Dall.
Corbula cuneata Say.
Corbula inaequalis Say.
Corbula heterogenea Guppy.
Crassatellites (Crassinella) duplinianus Dall.
Crassatellites (Crassinella) lunulata Conrad.
Crassatellites Gibbesii Tuomey and Holmes.
Crassatellites psychopterus Dall.
Crassatellites undulatus Say.
Crenella duplinensis Dall.
Cumingia medialis Conrad.
Cyrena (Pseudocyrena) dupliniana Dall.
Diplodonta acclinis Conrad.
Diplodonta nucleiformis Wagner.
Divaricella quadrisulcata d'Orbigny.
Donax emmonsi Dall.
Donax fossor Say.
Dosinia elegans Conrad.
Ensis directus Conrad.
Ensis ensiformis Conrad.
Ervilia lata Dall.
Erycina carolinensis Dall.
Gafrarium (Gouldia) metastriatum Conrad.
Gastrochaena ligula H. C. Lea.
Gemma magna Dall.
Gemma trigona Dall.
Glycymeris americana de France.
Glycymeris duplinensis Dall.
Glycymeris pectinata Gmelin.
Glycymeris pennacea Lamarck.
Glycymeris subovata Say.
Glycymeris subovata Say var. *plagia* Dall.
Hindsiella acuta Dall.
Hindsiella carolinensis Dall.
Leda acuta Conrad.
Leda hypsoma Dall.
Lima carolinensis Dall.
Macoma Conradi Dall.
Macoma (Psammocoma) holmesii Dall.
Macrocallista reposta Conrad.
Margaritaria abrupta Conrad.
Metis magnoliana Dall.
Modiolaria carolinensis Dall.
Modiolus ducatelii Conrad.
Mulinia congesta Conrad.
Mulinea lateralis Say.
Mulinea milesii Holmes.
Mytilus conradinus d'Orbigny.
Nucula taphria Dall.
Ostrea compressirostra Say.

Ostrea sculpturata Conrad.
Pandora (Kennerleyia) arenosa Conrad.
Pandora (Clidophora) crassidens Conrad.
Pandora (Clidophora) trilineata Say.
Panopea reflexa Say.
Paramya subovata Say.
Pecten (Lyropecten) jeffersonius var. *septenarius* Say.
Pecten (Plagioctenium) eboreus Conrad.
Petricola carolinensis Dall.
Phacoides anodonta Say.
Phacoides contractus Say.
Phacoides crenulatus Conrad.
Phacoides cribrarius Say.
Phacoides densatus Conrad.
Phacoides multistriatus Conrad.
Phacoides radians Conrad.
Phacoides tuomeyi Dall.
Pitaria filosina Dall.
Placunanomia plicata Tuomey and Holmes.
Plicatula marginata Say.
Rangia clathrodonta Conrad.
Rochefortia stantoni Dall.
Rochefortia stimpsoni Dall.
Saxicava arctica Linné.
Semele bella Conrad.
Semele bella var. *appressa* Dall.
Semele bella var. *duplinensis* Dall
Semele carinata Conrad.
Semele (Semelina) nuculoidea Conrad.
Sphenia dubia H. C. Lea.
Spisula curtidens Dall.
Spisula duplinensis Dall.
Spisula magnoliana Dall.
Sportella constricta Conrad.
Sportella protexta Conrad.
Strigilla flexuosa Say.
Tellina arctata Conrad.
Tellina (Angulus) dupliniana Dall.
Tellina (Angulus) macilenta Dall.
Tellina (Angulus) umbra Dall.
Transennella carolinensis Conrad.
Tugoniopsis compacta Dall.
Venericardia (Cyclocardia) granulata Say.
Venericardia (Pteromeris) perplana Conrad.
Venericardia (Pteromeris) perplana var. *abbreviata* Conrad.
Venericardia (Pleuromeris) tridentata Say.
Venus campechiensis Gmelin.
Venus plena Conrad.
Venus tridacnoides Lamarck.
Verticordia emmonsi Dall.

BRACHIOPODA:
Discinisca lugubris Conrad.

About ½ mile west of Magnolia there are several sinks. One is perhaps 100 feet in diameter. It contains water to within a few feet of the surface in the form of a pond without an outlet. Its depth is uncertain, but not now very deep.

Near the preceding is another shallow pond which has an outlet to the west.

Another about ¼ mile west of the preceding is now dry, except that a spring comes out of its side and the water sinks from sight at its bottom. This one is 20 to 25 feet in depth.

On the side of this sink a light greenish calcareous sand was observed which contains a few *Echinoderms*. There is a channel off to one side of this pit which looks like a former outlet. There are probably other sinks in the woods to the south of this.

On F. M. Wilson's farm, 1 mile east of Magnolia, Duplin County, N. C., Miocene shell marl has been dug. (See Plate XI, B, opposite p. 249.)

The pit has been excavated to a depth of some 8 or 10 feet. The marl consists principally of a mass of small gastropod and bivalve shells. They are soft when first exposed, but harden in the sun.

About 1½ miles north of Magnolia, N. C., along a drainage ditch just east of the railroad the marl is exposed in sides of ditch. In almost every particular it resembles the marl at the Natural Well and is evidently part of the same bed. A few fossils found here were not observed at Natural Well and *vice versa,* yet the general assemblage of forms is the same. The shell marl seems to form a continuous bed that underlies the whole region about Magnolia and extends westward into Sampson County. In some places it is covered by only about 3 or 4 feet of sand; in other places it is only struck at depths of 18 or 20 feet.

On Mr. M. H. Kornegay's place, about 4 miles northeast of Magnolia, marl has been dug along a small branch. The specimens collected seem to represent practically the same marl bed as that at Natural Well.

Also on Mr. Frank Wilson's farm, about 1 mile east of Magnolia, marl has been dug. The marl could not be seen in place, as the hole was filled with water, but from the appearance of a heap of marl that had been thrown out, it seems that it is the same marl bed that appears at Natural Well. A number of shells of the same species as occur at Natural Well were recognized.

SECTION OF WELL AT BEAUFORT, N. C.

	Feet.
Pleistocene:	
Loose medium-grained sand	1- 12
Gray calcareous clay with a few shells	12- 13
Loose gray sand with an admixture of dark grains	13- 17
Gray calcareous clay with a few shell fragments	17- 25
Pliocene (?) and *Miocene* (Duplin):	
Loose gray sand with shells largely fragmentary: *Oliva* sp., *Pecten* sp., *Venericardia tridentata, Venus* sp., *Tornatina canaliculata, Turbonilla reticulata, Mulinia lateralis, Nucula proxima*	25- 80
Loose gray sand with magnetite grains and fine shell fragments	80-118
Coarse sand, the grains very irregular; contains some shell fragments	118-120
Greenish-gray, slightly argillaceous sand, with some shell fragments. *Mactra* sp., *Mulinia lateralis*	120-196
Fragments of small shells, principally small barnacles, *Mulinia lateralis, Pecten eboreus*	196-213
Loose gray sand with fine shell fragments: *Balanus* sp., *Tellina* (?) sp.	213-238

One Mile Southeast of Watha, Pender County.—Where the wagon road crosses Lewis Creek on the farm of D. J. McMillan, marl was

once quarried for fertilizing purposes. The material seems to have been mainly Miocene, though some Eocene phosphatic conglomerate was obtained in the bottom of the pit.

SECTION OF WELL AT NORTHEAST CORNER OF THIRD AND NUNN STREETS, WILMINGTON.

	Feet.
No sample (probably Pleistocene)	1-35
Miocene (Duplin):	
1. White, fine-grained, clean, loose, slightly micaceous sand	35-48
2. Light gray, medium-grained, calcareous sand with a few small *Pelecypods* and *Gastropods* (one young individual of *Polynices* observed, and one *Bryozoan*)	50-58
(Eocene does not appear to be present.)	
Marine Cretaceous:	
3. Light gray, fine-grained, calcareous, slightly micaceous sand, containing numerous very small fragments of shells	60-62
Total depth	115

DUPLIN FOSSILS FROM EXCAVATION IN WILMINGTON.

ARTHROPODA:
Balanus concavus Bronn.

GASTROPODA:
Crepidula aculeata var. *costata* Morton.
Crepidula fornicata Linné.
Crepidula plana Say.
Fasciolaria rhomboidea Rogers.
Littorina irrorata Say.
Marginella bella Conrad.
Marginella limatula Conrad.
Oliva mutica Say.
Oliva litterata Say.
Polynices duplicatus Say.
Polynices heros Say.
Terebra dislocatus Say.
Vermetus graniferus Say.

PELECYPODA:
Anomia simplex d'Orbigny.
Arca adamsi Smith.
Arca improcera Conrad.
Arca lienosa Say.
Arca limula Conrad.
Astarte symmetrica Conrad.
Astarte concentrica Conrad.
Callocardia sayana Conrad.
Cardita arata Conrad.
Cardium robustum Solender.
Chama congregata Conrad.
Chione cribraria Conrad.
Chione latilirata Conrad.
Crassatellites gibbesii Tuomey and Holmes.
Crassatellites undulatus Say.
Corbula inaequalis Say.
Corbicula densata Conrad.
Diplodonta acclinis Conrad.
Divaricella quadrisulcata d'Orbigny.
Echinochama arcinella Linné.
Ensis ensiformis Conrad.
Glycymeris americana de France.
Glycymeris subovata Say var. *plagia* Dall.
Glycymeris pectinata Gmelin.
Macrocallista reposta Conrad.
Mulinia lateralis Say.
Nucula proxima Say.
Ostrea compressirostra Say.
Ostrea sculpturata Conrad.
Panopea reflexa Say.
Phacoides anodonta Say.
Phacoides radians Conrad.
Pecten eboreus Conrad.
Plicatula marginata Say.
Rangia clathrodonta Conrad.
Spisula subparilis Conrad.
Venericardia granulata Say.
Venericardia tridentata Say.
Venus mercenaria Conrad.
Venus rileyi Conrad.

ANTHOZOA:
Septastrea marylandica Conrad.

SECTION OF WELL AT ST. HELENA, 2½ MILES SOUTH OF BURGAW, PENDER COUNTY.

Pleistocene:	FEET.
Gray clay	0-10
Marl, consisting of chunks of dark gray, calcareous, sandy clay, coarse sand and gravel with pebbles up to ½ inch in diameter and fragments of fossils, *Ostrea*, *Echinoid* spines, etc.	10-20
Miocene (Duplin):	
Yellow marl, consisting of coarse sand and gravel with pebbles up to ¼ inch in diameter, pieces of yellow limestone rock, phosphate pebbles up to ¼ inch in diameter, chunks of gray clay, and many fragments of fossils, *Venericardia*, other *Pelecypods*, *Gastropods*, *Echinoid* spines, etc.	20-30
Fine, dark greenish-gray micaceous, calcareous, glauconitic sand with scattered fragments of fossils	30-40
Fine, gray glauconitic sand with phosphate pebbles up to ⅛ inch in diameter, and many shells and fragments of shells, *Arca*, *Venericardia*, *Spisula* (?), *Balanus*, *Ostrea*, *Bryozoa*, *Glycymeris*, etc.	40-60
Cretaceous (Peedee):	
Dark gray, finely micaceous, glauconitic sand and sandy clay	60-70
Total depth	220

At Bolton in a well section the Miocene, consisting of light gray, coarse-grained sand with shell fragments, is 10 feet thick and was encountered at 40 feet from the surface. It is overlain by Pleistocene and underlain by Peedee. Three-fourths of a mile southwest of Freeman, Tertiary (Pliocene (?) and Miocene) strata were encountered at depth of 15 feet and apparently extended to 146 feet.

In a well ½ mile east of Robeson, Miocene extends from 30 feet to 40 feet—coarse sand and gravel with shell fragments. It contains the following fossils:

GASTROPODA:
Tornatina canaliculata Say.
PELECYPODA:
Arca sp.
Asaphis centenaria Conrad.
Astarte concentrica Conrad.
Cardium sublineatum Conrad.
Corbula inaequalis Say.
Crassatellites sp.
Glycymeris subovata Say.
Ostrea sp.
Pecten eboreus Conrad.
Venericardia sp.

Along the northern shore of Lake Waccamaw the Miocene is exposed continuously for about a mile, extending from the pumping station eastward. About ¼ mile east of the pumping station of the A. C. L. Railroad the following section is exposed:

Pleistocene:	FEET.
Pink and yellow loamy sand or clay	10-15

Miocene (Duplin):	Feet.
White to yellowish shell marl consisting of entire and broken shells in a matrix of sandy clay	2-6
Compact fossiliferous limestone, containing many casts of Molluscan fossils. Casts of *Crepidula* are especially abundant in the upper part, while in the lower portion of the limestone *Pecten mortoni* occurs. Other forms are also present	1-6
Yellowish-brown calcareous sand, containing many irregular nodules of calcium phosphate. some of which are several inches in diameter. Some of the phosphatic pebbles seem to be worn casts of Cretaceous *Mollusca*. This layer seems to form a basal conglomerate in the Miocene	½-1
Dark gray micaceous sand extending to water's edge	2

The loose shell marl and the underlying fossiliferous limestone seem to be almost identical, in general character, with deposits which form the upper part of the Miocene in South Carolina and well exposed along the Peedee River in the vicinity of Bostick. There is no doubt but that they represent the same horizon.

At Elizabethtown on the Cape Fear River the Pleistocene rests directly upon the Cretaceous, but a short distance to the south of town the Miocene marls appear between the two. One poor exposure occurs along the main road, 1½ miles south of Elizabethtown on the south slope of the valley of Brown's Creek. A better exposure occurs 4 miles south of Elizabethtown at Hammonds Creek. Here there is an outcrop of Miocene marls about 20 feet in thickness. The section exposed is as follows:

Miocene (Duplin):	Feet.
Shell bed composed almost entirely of shells in a matrix of fragmentary material. *Mulinia congesta* being especially abundant	5
Bluish drab clay containing many pockets of fine white sand	1
Sandy clay and sands poorly exposed	6-10
Shell bed in which a narrow species of *Ostrea* is present in large numbers, poorly exposed	1-5

In the same vicinity the marl bed is covered with Pleistocene.

Four Miles South of Clarkton, on Brick Yard Branch.—Marl has been reported to occur in this region extending as far as Whiteville in a number of different places. The marl has been dug extensively, though not within the past few years.

Four Miles North of Lumberton, on the Lumberton and Fayetteville Road.—Marl has been dug at this place in the past, though none of it is exposed at the present time.

A.—Exposure of limestone of the Duplin formation, replete with casts of Crepidula; north shore of Waccamaw Lake, Columbus County, N. C.

B.—Exposure of limestone of the Duplin formation; north shore of Waccamaw Lake, Columbus County, N. C.

A.—Marl pit in the St. Marys formation, eight or nine miles west of Greenville, Greene County, N. C.

B.—Marl pit in the Duplin formation, one mile east of Magnolia, Duplin County, N. C.

One Mile West of Lumberton.—Marl was dug at this locality years ago, and consisted of a rather large variety of fossil shells, included in a sandy matrix which, in places, has been cemented together to form calcareous sandstone.

Left Bank of Lumber River, Lumberton.—Section poor, but at one place there is a shell bed a foot thick which does not seem to have any considerable extent along the river. The matrix is iron-brown sand and contains many fragments of shell and some black phosphatic pebbles.

Four or five miles below Lumberton, left bank of Lumber River, the following section occurs:

	Feet.
Pleistocene:	
Yellowish-brown sand, loose	3
Loose white fine sand	6
Fine loose sand, purplish red	1
Yellowish-brown sand	1
Miocene (Duplin):	
Drab and purplish-red stratified clay	2
Miocene shell marl bed with matrix of yellowish sand	4
Concealed to water's edge by talus and vegetation.	

For the next mile or so high land is near the river on the left. The stream then enters a swamp and winds about in long loops back and forth across the flood plain. This continues for 8 or 10 miles to Matthew's Bluff, right bank. No good section of this bluff is exposed. About 3 feet above water's edge there is a poor exposure of stratified drab clay and yellow sand. This resembles some of the Miocene materials seen in the preceding section.

The bluff is about 10 feet high and its top is level with the surrounding country.

One and Three-fourths Miles Northeast of Fairmont, Robeson County.—Marl has been dug in several places along the tributaries of Hog Swamp. Specimens of the marl can still be seen about some of the old marl pits that are now filled with water. The matrix consists of a gray to blue sand containing many shell fragments, and some of the shells show evidence of having been water-worn.

Marl is also said to have been encountered in wells in the town of Fairmont.

Two Miles Northwest of Barnesville, Robeson County.—Old marl pits occur in this section, though no marl has been dug within recent years.

PLIOCENE.

WACCAMAW FORMATION.

Name.—The Waccamaw formation receives its name from the Waccamaw River in South Carolina, where fossiliferous deposits are well developed and where extensive collections have been made definitely determining the Pliocene age of the exposures. The name "Waccamaw beds" was first proposed by Dall in his Tertiary Fauna of Florida in 1892,[1] and an extensive list of the fossils was published on pages 210-213 of the same report. The name is again used by Dall in his Table of North American Tertiary Horizons,[2] and is also included in his Correlation Table facing page 334. Mr. Earle Sloan, State Geologist of South Carolina, uses the name in his report on the geology of the State included in the Handbook of South Carolina, page 92, 1907.

Definition.—The Waccamaw formation includes all the marine Pliocene deposits thus far recognized in North Carolina, with the exception of the doubtful Croatan deposits, and constitutes the uppermost marine Tertiary deposits of the State. It is best developed in the southern part of the State, no outcrops of it appearing, so far as known, to the north of the Neuse River.

The Waccamaw strata overlie deposits of earlier age in the southeastern part of the State, these earlier formations ranging from the Peedee Cretaceous to the Duplin Miocene. In a well boring in Hyde County the record seems to show the presence of the Waccamaw which is in immediate contact with the Yorktown Miocene deposits. In Craven and Carteret counties it is not known what deposits underlie the Waccamaw, but it seems not improbable that in some places it is the Trent Eocene.

Along the Cape Fear River the Waccamaw is in contact with the Peedee Cretaceous, and it occupies a similar relation along the Waccamaw River in South Carolina.

The formation is overlain by Pleistocene in every locality where it has been recognized. In most places the overlying materials consist of unfossiliferous quartz sands of light color, but in Hyde County in a well near Lake Landing, previously mentioned, Pleistocene strata containing marine fossils are found immediately above the Waccamaw.

The Waccamaw formation is unconformable with all of the formations with which it is in contact.

Lithologically the Waccamaw formation closely resembles the Miocene Yorktown formation. It consists of loose gray to buff fine quartz

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[1]Wagner Free Institute of Science Trans., Vol. III, Part II, 1892, p. 209.
[2]Eighteenth Annual Report of the U. S. Geological Survey, Part II, p. 337.

A.—Exposure of limestone of the Duplin formation, north shore of Waccamaw Lake, Columbus County, N. C.

B.—Lime sink known as "Natural Well," two miles southwest of Magnolia, Duplin County, N. C.

sands in which occasional small quartz pebbles are present. It also, in places, contains a small number of black, water-worn phosphatic pebbles that have evidently been derived from the Cretaceous.

Beside the sands of the formation, the shell marls are of greatest importance. Along the lower Neuse River in the vicinity of Slocum Creek and Croatan the quartz sands contain numerous perfectly preserved fossils, some of which have undergone so little change that they can scarcely be distinguished from recent shells. It is possible that some of these beds may later prove to be Pleistocene. The sandy matrix in which they are found is buff to gray when weathered, but when fresh, greenish-blue and somewhat plastic on account of the admixture of considerable argillaceous matter.

Along the Cape Fear River the Waccamaw deposits are well developed in two localities, viz., Neill's Eddy Landing near Cronly and Walker's Bluff, about 9 miles from Rosindale. In both of those localities the shell marl constitutes the most important part of the formation and consists of excellently preserved fossils in a matrix of sand and fine shell fragments. At the marl pits of B. F. Keith at Neill's Eddy Landing the marl has been extensively dug and certain parts of it contain so little material, other than the shells, that analyses show the marl to consist of from 80 to 95 per cent calcium carbonate. At Walker's Bluff there is a thin layer of plastic clay that is somewhat calcareous and seems to constitute a part of the formation.

The total thickness of the Waccamaw formation is not known. It is probably, however, a comparatively thin one as developed in North Carolina, though part of it may have been removed by erosion in all of the localities where known. In a well section near Lake Landing in Hyde County 20 feet of materials are referred to the formation. Along the Neuse River the thickness is unknown. At Neill's Eddy Landing and Walker's Bluff the total thickness seems to be less than 20 feet. So far as we have any definite evidence at the present time the maximum thickness of the formation may be stated to be not more than 20 to 25 feet.

As shown by the lists of fossils from Neill's Eddy Landing and Walker's Bluff, given on later pages, the Waccamaw formation has yielded a very large variety of fossil species. These lists are far from complete, as there are many new species found at both of these localities which have not as yet been studied. When the determination of the fossils from these localities has been completed it is probable that the Waccamaw formation will be found to be even richer in the number of species than the Duplin, which has yielded so many forms at the Natural Well and other places in Duplin County. The fossils from this formation are, in general, well preserved.

The areal extent of the Waccamaw formation is not well known at present. It has been recognized in a well section in Hyde County, with a considerable degree of certainty. It occurs south of the Neuse River in Craven County and in the western part of Carteret County, and again in the northwestern part of Brunswick, northeastern part of Columbus, and southeastern part of Bladen counties. These areas are disconnected, though they were probably united at one time. Pre-Pleistocene erosion, of which there is much evidence as shown by the unconformable contact of the Pleistocene deposits resting upon the Waccamaw, undoubtedly removed the Pliocene strata in the intermediate areas. Northeastward the formation probably extends into Dare, Tyrrell, and Currituck counties, where it may later be recognized in well borings, though no such data are available now.

Southward the Waccamaw of the Cape Fear River region is not known to be continuous with the formation in northeastern South Carolina. There is some evidence which points toward the presence of the formation in the lower part of Brunswick County, though the evidence is not conclusive.

The Waccamaw formation overlies beds of various ages and occupies depressions in the pre-Pliocene surface. In the vicinity of Cronly the formation dips toward the Cape Fear River, but at a low inclination. It is at that point at a higher level than the deposit along the Waccamaw River in South Carolina, which indicates a gentle dip toward the ocean.

Detailed Sections.

SECTION OF WELL 2½ MILES SOUTHEAST OF LAKE LANDING, HYDE COUNTY.

	FEET.
Pleistocene or *Pliocene:*	
Loose gray fossiliferous sand, fossils mostly fragmentary: *Nassa* sp., *Pecten* (?) sp., *Balanus* (?) sp., *Eulima* (?) sp., *Mulinia lateralis*	6-40
Loose gray fossiliferous sand, fossils mostly fragmentary: *Pecten* (?) sp., *Foraminifera, Leda acuta, Crepidula fornicata, Arca* sp., *Ensis* sp., *Ostrea* sp., *Phacoides multilineatus, Venericardia* sp., *Columbella* (?) sp., *Mangilia* (?) sp., *Terebra* (?) sp., *Turbonilla* (?) sp., *Tornatina canaliculata, Mulinia lateralis, Nucula proxima*..................................	40-60
Fine loose gray sand with some shells and shell fragments: *Crepidula fornicata, Leda acuta, Phacoides* sp., *Pecten* sp......	60-80
Pliocene (Waccamaw):	
Fine loose gray sand, very fossiliferous, fossils mostly fragmentary: *Crepidula fornicata, Fissuridea* sp., *Nassa* sp., *Polynices duplicatus, Scala* sp., *Arca* sp., *Callocardia* sp., *Ensis* sp., *Leda acuta, Pandora* sp., *Phacoides multilineatus, Phacoides amiantus, Phacoides tuomeyi, Venericardia tridentata,* Echinoid spines, *Eulima* (?) sp., *Marginella* sp., *Olivella* (?) sp., *Olivella*	

FEET.

mutica (?), *Terebra dislocata*, *Turbonilla reticulata*, *Turritella* sp., *Corbula* sp., *Corbula barratiana*, *Gemma magna*, *Mulinia lateralis*, *Nucula proxima* 80-100

Miocene (Yorktown and St. Marys?):

Very fine loose gray sand with a few shell fragments: *Callocardia* (?) sp., *Chione* (?) sp., *Gemma* (?) sp., *Phacoides* sp., *Yoldia laevis* (?)..100-120

Loose gray calcareous, slightly argillaceous sand, fossiliferous: *Crepidula fornicata*, *Teinostoma* sp., *Callocardia* (?) sp., *Leda acuta*, *Nucula proxima*, *Phacoides* (?), *Venericardia granulata*.120-140

Consists largely of shells and shell fragments, with a small amount of gray sand: Echinoid spines, *Cadulus thallus*, *Caecum carolinianum*, *Dentalium attenuatum*, *Crepidula fornicata*, *Fulgur* sp., *Marginella* (?) sp., *Marginella* (*Volutella*) sp., *Nassa* sp., *Eulima* (?) sp., *Polynices duplicatus*, *Scala* sp., *Scila adamsi*, *Teinostoma nanum*, *Tornatina canaliculata*, *Turbonilla interrupta*, *Turbonilla reticulata*, *Turritella* sp., *Astarte undulatus*, *Callocardia sayana*, *Cardium* sp., *Chione latilirata*, *Corbula*, *Leda acuta*, *Nucula proxima*, *Nucula taphira*, *Pandora* sp., *Phacoides crenulatus*, *Tellina* sp., *Venericardia granulata*, *Verticordia emmonsi*, *Yoldia laevis*.............................140-160

Loose gray sand, with a large amount of shell material, mostly in a comminuted condition: *Cadulus thallus*, *Dentalium attenuatum*, *Tornatina canaliculata*, *Turbonilla* sp., *Astarte concentrica*, *Ensis* sp., *Leda acuta*, *Nucula proxima*, *Pandora crassidens* (?), *Phacoides crenulatus*, *Tellina* sp., *Venericardia granulata*, *Yoldia laevis*.......................................160-180

Loose gray, rather coarse fossiliferous sand. Fossils mostly fragmentary: *Bryozoa*, Echinoid spines, *Dentalium attenuatum*, *Crepidula fornicata*, *Nassa* sp., *Olivella mutica* (?), *Turbonilla interrupta*, *Astarte concentrica*, *Callocardia sayana* (?), *Cardium* sp., *Corbula* sp., *Ensis* sp., *Leda acuta*, *Nucula proxima*, *Phacoides crenulatus*, *Tellina* sp., *Venericardia granulata*, *Yoldia laevis* 180-200

RIVERDALE WHARF, RIGHT BANK OF NEUSE RIVER, 9 MILES BELOW NEW BERN.

At this place there is a bluff about 18 feet in height in which the following section is exposed:

Pleistocene: FEET.

Laminated alternating drab clay and sand layers, poorly exposed.. 12-15

Pliocene (Waccamaw):

Indurated ferruginous sandstone containing many small quartz pebbles, few larger than a pea in size. The rock contains many fossil casts of *Pecten*, *Ensis*, *Leda*, *Cardium*, etc. The rock varies in the amount of induration. Exposure about.......... 4

Compact drab clay poorly exposed........................... ½-1

The lower part of this section is undoubtedly Pliocene or Pleistocene, but the fossils that are represented by casts are not distinctive. However, it is probable that the strata belong to the same period as those exposed at Slocum Creek, and probably will be found to be of Pliocene age.

Slocum Creek, Neuse River.—Along Slocum Creek shell marl was dug a number of years ago and was extensively used as a fertilizer. Mr. Mallinson is reported to have dug large quantities. At present no marl is exposed along the creek, but along the Neuse River a short distance above the mouth of Slocum Creek the marl outcrops just beneath the water. In one or two places the blue clay is exposed for a few inches above the water. On the beach many fossils are exposed which have been washed from the blue clay in which they occur. The excellent state of preservation of the fossils, as well as the forms that are present, indicate the comparatively recent age of the beds. It is probable that they form a part of the upper Pliocene. Sufficient work in the determination of the fossils has not as yet been done to definitely settle this point, and for that reason they are retained in the Pliocene, where they have formerly been placed.

One-fourth Mile West of Croatan Station, Craven County.—Shell marl is found at a depth of 5 feet from the surface in a bluish-gray sandy matrix.

One and One-half Miles East of Lake Ellis, Craven County.—Marl has been dug at this place, in which were many shells contained in a matrix of rather coarse sand with lenses of bluish-gray argillaceous sand. This marl is probably of Pliocene age.

In the vicinity of Newport, Carteret County, marl has been reported to occur in which bones seem to predominate instead of shells.

Two Miles North of Kuhns and 1 Mile East of White Oak River.—On the Frog Point plantation marl has been recently dug. The section exposed is as follows:

	Feet.
Pleistocene:	
Deep chocolate, loose brown, fine-grained sandy loam, colored dark by organic matter	3
Similar material, but lighter in color and more sandy	2
Pliocene (Waccamaw):	
Shell bed, perfect shells in a matrix of a fine-grained drab to black argillaceous sand with some pebbles 2 inches in diameter	1
Blue-gray marl filled with shells in an excellent state of preservation	3

One-fourth Mile Northeast of Kuhns, Carteret County.—At this place marl has recently been dug. The section is as follows:

Pleistocene:	FEET.
Gravelly sand with some pebbles as much as 1½ inches in diameter, a few black phosphatized pebbles and water-worn sharks' teeth	4-5
Pliocene (Waccamaw):	
Very coarse sand cemented by calcium carbonate and slightly stained with iron. Contains few shell fragments	1-1½
Blue to drab sand in which are many shells, sharks' teeth and bones	2½-3
Cobble bed with some of the pebbles as much as 3 inches in diameter exposed in base of pit.	

The Pliocene marl beds seem to occur in patches in the vicinity of Cape Fear River. An instance of this is shown about 13 miles northwest of Wilmington in the vicinity of Northwest Station. There two borings were made with an auger to determine the extent of the marl, but in neither case was the Pliocene marl encountered. The Pleistocene rests directly upon the Cretaceous. Only a few hundred feet away from the place where the borings were made the Pliocene marl outcrops and in character appears to be similar to that exposed in the marl pits of B. F. Keith at Neill's Eddy Landing on Cape Fear River. In one place the bed is at least 8 feet thick. The matrix consists principally of broken shells in which are many perfect shells.

Neill's Eddy Landing, Cape Fear River.—At this place fossiliferous Pliocene strata are well exposed, overlying Cretaceous beds. The shell marl has been extensively dug and is ground, bagged, and shipped for use as a fertilizer. The shell marl is about 10 feet in thickness and is made up almost exclusively of shells in a good state of preservation, contained in a matrix of broken shells. A small amount of quartz sand is present, but that this is a minor constituent is shown by the high percentage of calcium carbonate that is shown in the analyses. Some of the analyses show over 90% of calcium carbonate, while most of them run about 80%. Some calcium phosphate is also present. Black phosphatic pebbles from ½ to 2 inches in diameter are irregularly distributed through the marl. At this place extensive collections have been made and a wide variety of species determined.

An analysis of a phosphate nodule occurring in the marl showed a considerable amount of phosphoric acid. The more calcareous portions of the marl consist almost entirely of $CaCo_3$.

How extensive the deposit of Pliocene marl is can scarcely be determined because of the absence of exposures due to the level character of the surrounding country. At Cronly there is a large pit where the Cretaceous marl has been dug extensively for fertilizing purposes, and here the Pliocene marl overlies the Cretaceous, but is extremely thin. In

a few places in the pit it is only 2 or 3 inches thick, but in other places is more than 1 foot in thickness. The lithologic character of the material is similar to that at Neill's Eddy Landing. Similar marl beds are reported to occur in numerous places to the south and southeast of Cronly. Near Bolton marl has been dug which may be of Pliocene age, though it is more probable that it is part of the same bed that outcrops along the shores of Lake Waccamaw, and which carries Miocene fossils.

The number of species of fossils obtained at Neill's Eddy Landing is very large, as shown by the following list, and many new forms have not yet been described.

NEILL'S EDDY LANDING, N. C.

GASTROPODA:

Caecum carolinianum Dall.
Caecum cooperi S. Smith.
Caecum floridanum Stimpson.
Calliostoma wilcoxianum Dall.
Cancellaria carolinensis Emmons.
Conus adversarius Conrad.
Conus marylandicus Green.
Crepidula fornicata Say.
Crepidula plana Say.
Cyprea pediculus Linné.
Fasciolaria apicina Dall.
Fasciolaria rhomboidea Rogers.
Fissuridea carditella Dall.
Fissuridea nucula Dall.
Fulgur perversum Linné.
Fusus caloosaensis Heilprin.
Liotia gemma Tuomey & Holmes.
Marginella aureocincta Stearns.
Marginella dacria Dall.
Marginella limatula Conrad.
Murex rufus Lamarck.
Nassa trivittata Say.
Nassarina glypta Bush.
Oliva litterata Lamarck.
Polynices duplicatus Say.
Polynices internus Say.
Pyrula papyratia Say.
Terebra dislocata Say.
Tornatina canaliculata Say.
Turritella subannulata Heilprin.

PELECYPODA:

Abra aequalis Say.
Anomia simplex d'Orbigny.
Arca adamsi Smith.
Arca lienosa Say.
Arca limula Conrad.
Arca limula var. *platyura* Dall.
Arca rustica Tuomey & Holmes.
Astarte concentrica Conrad.
Cardita arata Conrad.
Cardium sublineatum Conrad.
Chione cribraria Conrad.
Chione latilirata Conrad.
Corbicula densata Conrad.
Corbula contracta Say.
Corbula inaequalis Say.
Crassatellites gibbesii Tuomey & Holmes.
Crassatellites lunulatus Conrad.
Diplodonta acclinis Conrad.
Divaricella quadrisulcata d'Orbigny.
Dosinia elegans Conrad.
Echinochama arcinella Linné.
Ensis directus Conrad.
Gafrarium metastriatum Conrad.
Glycymeris americana de France.
Glycymeris pectinata Gmelin.
Leda acuta Conrad.
Mactra n. sp.
Modiolus ducatelii Conrad.
Montacuta petropolitana Dall.
Mulinia lateralis Say.
Mytilus hamatus Say.
Nucula proxima Say.
Ostrea sculpturata Conrad.
Ostrea virginica Gmelin.
Pecten eboreus Conrad.
Pecten n. sp.
Phacoides anodonta Say.

Phacoides crenulatus Conrad.
Phacoides radians Conrad.
Phacoides trisulcatus Conrad.
Phacoides tuomeyi Dall.
Plicatula marginata Say.
Rangia clathrodonta Conrad.
Semele bella Conrad.
Sportella constricta Conrad.
Sportella protexta Conrad.
Strigella flexuosa Say.
Tagelus gibbus Spengler.
Transennella carolinensis Dall.
Venericardia granulata Say.
Venericardia perplana Conrad.
Venericardia tridentata Say.
Venus rileyi Conrad.

WALKER'S BLUFF, RIGHT BANK OF CAPE FEAR RIVER, 60 MILES ABOVE WILMINGTON.

	Feet.	Inches.
Pleistocene:		
Sandy loam	2	
Mottled reddish and yellowish arenaceous clay	1	6
Drab clay interstratified with yellowish to reddish sand	2	
Laminated drab clay, becoming arenaceous and with fine sand partings in lower half; basal 12 inches iron stained.	11	
Pliocene (Waccamaw):		
Coarse, loose, orange-colored sand	3	
Calcareous tough clay	...	6
Shell marl full of fossils, many perfectly preserved. The perfect specimens are in a matrix of fine shell fragments mixed in places with coarse buff sand. Thickens in places through dipping down in pockets or holes in Cretaceous. Gradually thins out and disappears in middle of bluff through being cut out by overlying Pleistocene. Again appears at bend. It contains some phosphate nodules and some sandstone cobbles 6 inches in diameter. The average thickness is about 5-6 feet, maximum	12	
Cretaceous:		
Laminated clays and sands, containing Cretaceous fossils in places, exposed to water's edge	48-51	

FOSSILS FROM WALKER'S BLUFF.

GASTROPODA:
Conus marylandicus Green.
Crepidula aculeata Gmelin var. *costata* Morton.
Crepidula fornicata Say.
Crepidula plana Say.
Eupleura caudata Say.
Fulgur canaliculatum Linné.
Fulgur perversum Linné.
Marginella limatula Conrad.
Nassa caloosaensis Dall.
Nassa lapenotierei Dall.
Nassa trivitatta Say.
Nassa vibex Say.
Oliva litterata Lamarck.
Polynices duplicatus Say.
Polynices heros Say.
Seila adamsi H. C. Lea.
Terebra concava Say.
Terebra dislocata Say.
Terebra protexta Conrad.
Tornatina canaliculata Say.
Turbonilla interrupta Totten.
Turbonilla reticulata C. B. Adams.

PELECYPODA:
Abra aequalis Say.
Aligena aequata Conrad.
Anomia simplex d'Orbigny.
Arca adamsi Smith.
Arca limula Conrad.
Arca plicatula Conrad.
Arca rustica Tuomey & Holmes.

Arca scalarina Heilprin.
Astarte concentrica Conrad.
Bornia triangula Dall.
Callocardia sayana Conrad.
Cardita arata Conrad.
Cardium oedalium Dall.
Cardium robustum Solander.
Cardium sublineatum Conrad.
Chama congregata Conrad.
Chione cribraria Conrad.
Chione grus Holmes.
Corbula barratiana C. B. Adams.
Corbula contracta Say.
Corbula inaequalis Say.
Crassatellites gibbesii Tuomey & Holmes.
Crassatellites lunulatus Conrad.
Diplodonta acclinis Conrad.
Diplodonta nucleiformis Wagner.
Divaricella quadrisulcata d'Orbigny.
Donax emmonsi Dall.
Echinochama arcinella Linné.
Ensis directus Conrad.
Erycina carolinensis Dall.
Gafrarium metastriatum Conrad.
Gemma magna Dall.
Gemma trigona Dall.
Glycymeris americana de France.
Glycymeris pectinata Gmelin.
Leda acuta Conrad.
Macrocallista nimbosa Solander.
Mulinia congesta Conrad.
Mulinia lateralis Say.
Mytilus hamatus Say.
Ostrea percrassa Conrad.
Ostrea sculpturata Conrad.
Ostrea virginica Gmelin.
Panopea reflexa Say.
Pecten eboreus Conrad.
Phacoides amiantus Dall.
Phacoides anodonta Say.
Phacoides crenulatus Conrad.
Phacoides radians Conrad.
Phacoides trisulcatus Conrad.
Phacoides tuomeyi Dall.
Plicatula marginata Say.
Rangia clathrodonta Conrad.
Strigilla flexuosa Say.
Tagelus gibbus Spangler.
Tellina dupliniana Dall.
Transenella carolinensis Dall.
Venericardia granulata Say.
Venericardia perplana Conrad.
Venericardia tridentata Say.
Venus campechiensis Gmelin.
Venus rileyi Conrad.

LAFAYETTE FORMATION.*

Historical Review.—The deposits in the Atlantic Coastal Plain States now designated the Lafayette formation were first differentiated by W J McGee[1] in 1888. In that paper the name "Appomattox" formation was introduced for a series of orange-colored sands, clays, and gravels occurring in a zone extending from near Fredericksburg, Va., to the Roanoke River in North Carolina. He says:

"In brief, the inland margin of the Appomattox formation, as exposed north of Roanoke River, is a moderately regularly stratified sand or clay with occasional intercalations of fine gravel, generally of pronounced orange hue, and without fossils; it reaches a thickness of probably 50 to 100 feet and forms the predominant surface formation over a zone 40 or 50 miles wide on the Roanoke, but alternates and narrows northward, finally disappearing at Potomac Creek, 4 or 5 miles north of Fredericksburg; and although it appears to thicken seaward, it soon disappears beneath tide level and newer deposits."

*By L. W. Stephenson.
[1]Am. Jour. Sci., 3d ser., vol. 35, 1888, pp. 328-330.

Concerning the stratigraphic relations of the formation in North Carolina, he says:

". . . at Weldon it rests upon deeply ravined crystalline rocks, save where inconspicuous remnants of Potomac arkose intervene, . . ."

"The formation is overlain only by the alluvium of small streams, eolian sands, etc., on the broad plains between Petersburg and Weldon, by occasional accumulations of wave-washed débris derived from its own mass in the extensive Quaternary terraces prevailing in its area, and by characteristic clays, sand, and gravels of the Columbia formations in the vicinity of the larger streams."

Concerning the extension of the formation southward, he says:

"The Appomattox formation is stratigraphically continuous with an extensive series of clays and sands investigated in North Carolina by Kerr, and referred by him first to the Quaternary and subsequently to the Eocene."

Concerning the age of the formation, he says:

"It is manifestly newer than the fossiliferous Miocene on which it rests, and older than the Columbia formation by which it is overlain."

He states his belief that at least a part of the "Orange sand" of Hilgard in Mississippi is equivalent to the "Appomattox" formation.

In this as well as in later papers he refers extensive areas of surficial deposits in North Carolina to this formation which in the present report are classed as Pleistocene terrace deposits.

In 1890 McGee[2] described somewhat more fully the distribution and character of the deposits in North Carolina which he included in his "Appomattox" formation.

In June, 1891,[3] a conference was held in San Francisco, which was participated in by Hilgard, Le Conte, Loughridge, and McGee, with the object in view of deciding upon an appropriate name to be applied to the scattered deposits which had been variously known by different investigators as "Orange sand," "Lagrange sand," "Appomattox" formation, etc., and which all agreed were synchronous in age. The name Lafayette which Hilgard had used originally in his field-notes to designate the formation, was agreed upon. The name is derived from Lafayette County, Miss.[4]

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[2]Am. Jour. Sci., 3d ser., vol. 40, 1890, pp. 15-41.

[3]U. S. G. S., Twelfth Ann. Rept., 1890-91, pt. 1, pp. 498-501; American Geologist, vol. 8, 1891, pp. 129-130.

[4]In a recent contribution E. W. Berry has questioned the appropriateness of the name "Lafayette" for these deposits. See Journal of Geology, vol. 19, No. 3, April-May, 1911: "The Age of the Type Exposures of the Lafayette Formation."

Later in the same year, 1891, a Monographic study by McGee[5] on the Lafayette formation appeared. Referring to North Carolina (pp. 485-486), he states that in areal distribution the formation extends from the fall line halfway to the coast. In stratigraphic position, it rests unconformably upon crystallines and various deposits of the Coastal Plain, up to and including the Miocene, and is overlain by sands of the Columbia group, which, however, are not well discriminated from it. The age of the formation is regarded as late Neocene. The deposits which McGee regarded as referable to this formation included not only the Lafayette formation as recognized by the present writer, but, in addition, probably all of the Coharie and Sunderland formations, and possibly a part of the Wicomico, Chowan, and Pamlico formations.

In 1893 J. A. Holmes[6] described the character, stratigraphic relations, and age of the surficial deposits of the sand-hill country, which, in North Carolina, lies to the east of the Piedmont border in the southwestern part of the Coastal Plain. In this region these materials consist of loams and sands which he regards as referable in part to the Lafayette formation and in part to the Columbia. The former rests with marked unconformity upon Cretaceous, and, to a limited extent, upon Eocene beds, and the latter, as a thin surface mantle, rests upon Cretaceous, Eocene, and Lafayette beds.

In their text-book, which appeared in 1906, T. C. Chamberlin and R. D. Salisbury,[7] discussing the origin of the Lafayette formation, conclude that the deposits representing the formation in the Atlantic Coastal Plain are largely of fluviatile and subaërial origin.

Definition.—The deposits of this formation are distributed as a more or less discontinuous surface covering in a belt 10 to 30 or 40 miles in width lying along the northwestern border of the Coastal Plain region. The inner margin of the belt was not studied in detail during the course of the present investigations, and for this reason the northwestern boundary of the Coastal Plain as mapped by Kerr is here accepted, with a few modifications, as limiting the Lafayette formation in that direction. Scattered beds of cobbles and gravels of fluviatile origin, probably synchronous at least in part with the Lafayette, occur in the Piedmont valleys far to the west of the main body of Coastal Plain deposits. The southeastern boundary of the Lafayette belt is marked by a seaward-facing slope or escarpment not everywhere sharply defined, which has not been traced in detail, but which has been recog-

[5]Lafayette Formation, U. S. G. S., Twelfth Ann. Rept., 1890-91, pt. 1, pp. 347-521.

[6]Geology of the Sand-hill Country of the Carolinas; Geol. Soc. Am. Bull., vol. 5, 1893, pp. 33-34.

[7]Geology, vol. 3, 1906, pp. 301-308.

nized at numerous places. This escarpment leads down from hills whose elevations exceed 230 feet to a more or less dissected plain, here designated the Coharie terrace plain, whose maximum elevation above sea level at the foot of the escarpment is about 230 or 235 feet.

The formation probably extends into South Carolina, but its distribution in that State is imperfectly known.

The formation rests with unconformable relations in part upon the basement rocks of the Coastal Plain, and in part upon beds of the Patuxent formation of the Cretaceous. The former relations exist from Cape Fear River northeastward to the Virginia line, crystallines forming the underlying rocks. From the Cape Fear southwestward to the South Carolina line the Lafayette deposits rest for the most part upon the Patuxent formation, but along the northwestern border of the belt they lap over upon the basement rocks, including both ancient crystallines and those of the Newark group (Triassic).

The deposits were laid down upon an extremely irregular surface which was produced by pre-Lafayette stream erosion. They have suffered much from erosion during post-Lafayette times and now exist as discontinuous sheets or patches which mantle the slopes or tops of the hills at elevations of from 230 to 400 feet or more above sea level. Throughout the Lafayette area the present surface presents an uneven aspect, consisting in part of smoothly rolling hills and in part of hills of a more rugged, angular character, in this respect contrasting strongly with the nearly level surface of the lower-lying Pleistocene terraces. The main topographic outlines of the region are believed to have originated during the pre-Lafayette erosion interval to which reference has just been made. This view is supported by the fact that the Lafayette deposits do not rest at concordant levels on the hills, but to greater or less extent mantle down over the existing valley slopes. It is probable that they originally partially filled the pre-Lafayette valleys, having been subsequently largely removed from the bottoms and lower parts of the slopes.

With the exception of wind-blown sands which are probably in part of Pleistocene and Recent age and which are present as an extensive surface covering in the sand-hill region, no post-Lafayette deposits are certainly known to rest upon the Lafayette beds.

The materials of the formation consist of sandy loams, sandy clays, sands and gravels. The coarser phases predominate. In places the sands are arkosic, the included kaolin grains having been derived in part from underlying Patuxent beds and in part from underlying or adjacent crystalline rocks. Sorting has not been thoroughly accomplished except locally, the sands and gravels as a rule containing a

more or less regularly disseminated clay content. At some places a large percentage of the pebbles and cobbles in the gravel beds are smoothly rounded, and this is especially true wherever there are considerable accumulations of gravel. Where very thin coverings of the deposits occur, however, resting directly upon the crystalline rocks a considerable percentage of angular or slightly worn quartz is, as a rule, intermixed with the well-worn material.

The materials of the Lafayette formation in most places present a dull or soft yellowish or reddish appearance, due to the presence of thin films of iron oxide coating the sand and clay particles. They differ in this respect from the unweathered sands and clays of the Patuxent formation which, as before stated, form the underlying strata over a part of the area, the latter being as a rule light in color, light drabs and grays prevailing. The Lafayette materials, however, are in some places light gray or mottled, and on the other hand the Patuxent materials where they have been subjected to long-continued surface weathering present iron oxide colorings, thus rendering it difficult at times to distinguish between the two formations.

The Lafayette formation where present forms a relatively thin surface covering, as a rule not exceeding 20 or 25 feet in thickness. The thickness varies, however, being much less in places and in places perhaps amounting to or exceeding 35 or 40 feet.

Detailed Sections.—Under this heading will be included descriptions of sections presenting materials regarded as typical examples of the Lafayette formation.

One of the best exposures of the formation in the State is afforded by a cut of the Seaboard Air Line Railway 1 mile west of Thelma in Halifax County. The position of the beds with relation to underlying crystalline rocks is shown in Fig. 15, p. 263.

The following features regarding the character and relations of the Lafayette materials in the above described exposure are deserving of especial emphasis: the irregularity of the surface of the crystallines on which they rest; the coarseness of texture; the smoothly rounded character of a large percentage of the pebbles and cobbles; the irregularity of the bedding; and the approximate conformity of the lines of stratification to the surface of the underlying crystallines.

The hills in the vicinity of Aurelian Springs in the same county are capped with yellowish and gray argillaceous sands, sandy clays, and gravels having an observed maximum thickness of about 30 feet, which rest directly upon decayed crystalline rocks. The gravels occur princi-

A.—Cobbles from the Lafayette formation in a field near the Weldon-Aurelian Springs road, one-half mile northeast of Aurelian Springs, Halifax County, N. C.

B.—Exposure of the Lafayette formation resting unconformably upon deeply decayed crystalline rock; cut of Seaboard Air Line Railway, one mile west of Thelma, Halifax County, N. C.

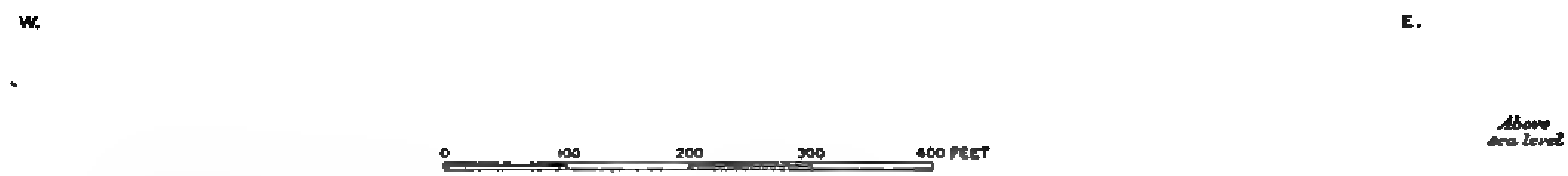


FIG. 15. Sketch showing relation of basement rocks to the Lafayette formation; cut of Seaboard Air Line Railway, 1 mile west of Thelma, N. C.

EXPLANATION OF FIGURE.

Lafayette formation:

1. Yellow argillaceous sand and sandy clay grading down into materials below.
2. Light gray, very coarse, arkosic, argillaceous sand with scattered pebbles and irregular lenses of gravel.
3. Pebbles and cobbles with gray argillaceous sand matrix.
4. Light gray, very coarse, arkosic sand with scattered pebbles.
5. Pebbles and cobbles having a maximum size of about 8 inches, with gray argillaceous sand matrix. Occasional crystalline bowlders along base.

Basement rocks:

6. Deeply decayed crystallines.

pally along the base of the sands and clays, their outcrops on the hill slopes being marked on the surface by great numbers of quartz pebbles and cobbles, the latter reaching a maximum diameter of 6 or 8 inches. A large percentage of the pebbles and cobbles are smoothly rounded. This locality is on the divide between Roanoke River and Fishing Creek, distant about 10 miles from the former and 14 miles from the latter. The elevation at Aurelian Springs, as determined roughly by aneroid readings, is about 300 feet above sea level. The hills between here and Littleton in the same county are capped by similar deposits. In many places the sedimentary materials are present as a very thin covering on the crystalline surface, and in such instances there is as a rule an intermixture of sharply angular quartz fragments in association with the more or less smoothly rounded pebbles and cobbles. A short distance northwest of Aurelian Springs the sands of the Lafayette contain in places enormous numbers of small arenaceous or argillaceous iron concretions.

Surficial deposits of the same general character and at comparable elevations were observed in the vicinity of Brinkleyville in this county.

Patches of Lafayette gravels, sands, and sandy clays are present capping the hills in the western part of Nash County, resting unconformably upon crystalline rocks at elevations ranging from 240 to 335 feet above sea level. These may be seen in the railroad cut at Springhope, and at various places along the road leading from Springhope to Rogers Crossroads by way of Gold Valley Crossroads, Samaria, Unionhope, and Dry Wells. (See Springhope Quadrangle.) Considerable accumulations of sand with basal gravel beds are present at more than 300 feet above sea level along the ridge on which Unionhope is situated.

Gravel beds are present in the northern part of Harnett County, resting unconformably upon the crystallines, but these have received but little study.

A number of good exposures of the formation are afforded by the cuts of the Seaboard Air Line Railway in Southeastern Moore County between the bridge over Crane Creek and Niagara station, a distance of about 7 miles. A short distance south of Crane Creek bridge at milepost 58 the Lafayette materials are seen to rest unconformably upon typical arkosic sands of the Patuxent formation. The latter is here present as a feather edge only, for, a few rods to the north, decayed crystallines appear above the level of the track. The relations of the formations are shown in the drawing, Fig. 16, and the character of the materials is described in the accompanying explanations.

A.—Thin veneer of materials from the Lafayette formation consisting of smoothly rounded pebbles and cobbles in a matrix of coarse sand, resting on closely underlying, deeply decayed, crystalline rocks near Samaria, Unionhope road, 1¼ miles southwest of Samaria, Nash County, N. C.

B.—Exposure of the Lafayette formation resting unconformably upon the Patuxent formation; cut of Seaboard Air Line Railway, 1 1-2 miles southwest of Lake View, Moore County, N. C.

A cut at Vass station, an exposure near the post-office at Lake View, and several cuts between Lake View and Niagara station reveal Lafayette materials occupying positions with reference to the underlying Patuxent beds similar to that shown in the figure to which reference has just been made. In places the contact is seen to be very irregular, as is true in the cut represented in the Fig. 9, p. 109 of this report. (See, also, Plate XV, opposite p. 264.)

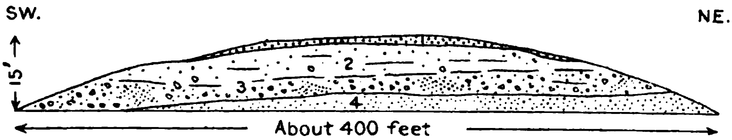


FIG. 16.—Sketch showing the relation of the Patuxent formation to the Lafayette formation; cut of Seaboard Air Line Railway, milepost 58, Moore County, N. C.

EXPLANATION OF FIGURE.

Lafayette formation:

1. Coarse, loose, gray sand.
2. Coarse mottled argillaceous sand with sandy clay lenses and scattered lenses of pebbles. Grades down into next layer.
3. Gravel layer 4 to 6 feet thick, consisting of moderately rounded to angular pebbles up to several inches in diameter with a coarse, yellow sand matrix cross-bedded in places.

Patuxent formation:

4. Stratified, gray, coarse, arkosic sand, streaked with yellow.

Gravel deposits, probably to be classed with the Lafayette formation, are present capping some of the hills in the vicinity of Pinehurst in Moore County, but these have not received careful study.

A long cut of the Seaboard Air Line Railway just north of Hamlet in Richmond County exhibits clearly the relations of the Lafayette beds to the underlying Patuxent formation. The following section describes with approximate accuracy the character of the materials revealed in any part of the cut, except that the two Lafayette layers vary considerably in thickness horizontally, and at certain places the Patuxent-Lafayette contact is somewhat obscured by weathering.

CUT OF SEABOARD AIR LINE RAILWAY JUST NORTH OF HAMLET, N. C.

Pliocene? (Lafayette formation):	FEET.
Coarse, loose, pebbly sand, gray at top, becoming a dull yellow towards base. Merges with the underlying red sand and gravel layer towards the north end	2-5
Red and mottled, coarse, argillaceous, more or less pebbly sand, with a partially discontinuous band of pebbles and cobbles along base. Iron crusts present along contact in places. The pebbles and cobbles are of all sizes up to 4 or 5 inches and vary in shape from angular to moderately well rounded	1-8
(Unconformity.)	

Cretaceous (Patuxent formation): FEET.

Coarse, cross-bedded, argillaceous, arkosic, varicolored sand, with subordinate clay lenses, and in places numerous rolled clay balls 10-20

THE QUATERNARY FORMATIONS.

BY L. W. STEPHENSON.

HISTORICAL REVIEW.

The surficial deposits of the Coastal Plain of North Carolina received but little systematic study prior to the investigations of B. L. Johnson in 1907. Such progress as was made towards the determination of their age, their origin, and the proper basis for their classification cannot be credited to any considerable extent to original investigations within the State. The classic contributions treating of this class of deposits have been made with particular reference to their occurrence in the Coastal Plain States to the north of North Carolina or in the Gulf Coastal Plain States, with only occasional descriptions of or discussions of their extension or supposed extension into or through North Carolina.

It is not our purpose to give an account of all the contributions which have either directly or indirectly tended to further this progress, for that would involve a complete historical treatment of the subject as it relates to the whole Coastal Plain. Only the more important contributions treating of these deposits in North Carolina or in the Atlantic Coastal Plain, including North Carolina, will be referred to in this review.

The first attempt at classification which included North Carolina in its scope was that of William Maclure[1] in 1809. All the Coastal Plain deposits are regarded as belonging to one division, which he calls the "Alluvium," and which he subdivides as follows:

1. Peat,
2. Sand and gravel,
3. Loam,
4. Bog iron-ore,
5. Nagel-fluh,
6. Calc-tuff,
7. Calc-sinter.

[1]Trans. Amer. Phil. Soc., vol. 6, 1809, pp. 411-428; Jour. de Phys., 69, 1809, pp. 204-213.

Essentially the same classification was given in publications by the same author in 1811,[2] 1817,[3] and 1818.[4]

An important contribution which marks a distinct advance in Coastal Plain knowledge was made by Lardner Vanuxem in 1827, through Dr. S. G. Morton.[5] It is stated that the materials occurring in the region covered by the "Secondary," "Tertiary," and "Alluvial" formations of the Atlantic Coast have been previously referred to by most writers as the "Alluvial," and as constituting a single deposit; others have used the general term Tertiary. Vanuxem recognizes in the Coastal Plain deposits three major divisions, namely, the "Secondary," Tertiary, and "Alluvial" formations. For the youngest of these, the "Alluvial," he proposes the following subdivisions:

Modern alluvial	Vegetable mould. River alluvium.
Ancient alluvial	White siliceous sand. Red-earth.

The ancient alluvial is described as occupying the highest elevations above the "Secondary" and Tertiary classes, and consequently was not formed by existing rivers. The white-sand division is thought to have originated by the leaching out of the coloring matter of the underlying red-earth. This division is said not to occur north of North Carolina, but is abundant in all of the States south of it. The modern alluvial is well characterized in the Southern States and consists of the *débris* of the rivers which has been thrown up against the masses of the older formations. He thinks that beyond doubt all the bones of the mammoth and other mammaliferous terrane quadrupeds found in this region belong to the two alluvials.

About the same time, 1827 and 1828, Elisha Mitchell published several papers[6] [7] combatting the view, apparently prevalent at that time, that the "Low Country" was produced by the addition of materials along

[2]Jour. de phys., de chim, et d'hist. nat., vol. 72, Paris, 1811. With map; pp. 137-165.

[3]Observations on the geology of the United States of America, with some remarks on the effect produced on the nature and fertility of soils by the decomposition of the different classes of rocks. With two plates. 12mo. Phila., 1817.

[4]Observations on the geology of the United States of America, with some remarks on the probable effect that may be produced by the decomposition of the different classes of rocks on the nature and fertility of soils. Two plates. Republished in Trans. Amer. Phil. Soc., vol. 1, n. s., 1818, pp. 1-91. Leon. Zeit., I, 1826, pp. 124-138.

[5]Geological observations of the Secondary, Tertiary, and Alluvial formations of the Atlantic Coast of the United States of America. (Arranged from the notes of Lardner Vanuxem.) Acad. Nat. Sci., Phila., Jour., vol. 6, 1827, pp. 59-71.

[6]Report of the Geology of North Carolina, pt. 3, Raleigh, 1827.

[7]Amer. Jour. Sci., vol. 13, 1828, pp. 336-347.

[illegible]

[illegible] Pleistocene period. He regards [illegible]. This is probably the locality in [illegible] from which Conrad described a [illegible]. The bone bed is doubtless of Pleistocene age.

The [illegible] of formation and geographical distribution of the swamp [illegible] was described by Ebenezer Emmons [illegible] 1860. He regards the swamp accumulations as of recent origin.

[illegible] pp. 171-184.

[illegible] 46, 1844, pp. 320-[illegible].

[illegible] 10, pt. 2, 1857, p. 166.

[illegible] of North Carolina. Pt. 2. Raleigh, 1860. 95 pages.

W. C. Kerr[1] in 1875 included the surficial deposits of the North Carolina Coastal Plain region in the Quaternary system. The materials are described as consisting of beds of pebbles, sand, and clay. He believes that the Coastal Plain region was submerged during at least a part of the glacial period and regards the Quaternary deposits as having been transported by the great floods resulting from the melting of the ice of the glacial period. He distinguishes three periods in the Quaternary, namely, "Glacial," "Champlain," and "Terrace."

In 1884 Kerr[2] described the character of the low-lying region adjacent to Cape Hatteras. He regards the formation of the great Dismal Swamp and other swamps as due to a subsidence of the region. The long, narrow hills which inclose the Pamlico and Albemarle Sounds are described as hills or dunes blown shoreward by the wind and thrown up into reefs and hillocks. The Hatteras region as a whole is described "as a sort of *delta*, whose materials are derived from the drainage of more than 100,000 square miles of the Atlantic slope."

The occurrence of fossil stumps of cypress in the Quaternary deposits on the southwest bank of Neuse River, 10 to 12 miles below the town of New Bern, was noted by J. A. Holmes[3] in 1885.

The name Columbia formation was proposed by W J McGee in 1886 for the Pleistocene deposits occurring in the District of Columbia. The character and distribution of the formation about Washington and in general throughout the Coastal Plain were described in a series of papers which appeared during the years 1886-1888. One of the most important of these contributions appeared in 1888.[4] He divides the Columbia formation into the fluvial phase and the interfluvial phase. Both phases are said to occur in the vicinity of Roanoke River in North Carolina. He states that the city of Weldon is located on a broad Quaternary terrace of the Roanoke, 60 feet above its tidal waters, and notes the occurrence of a practically continuous series of similar terraces from the Roanoke northward to the terminal moraine.

In 1890 the same author,[5] discussing the southern extension of the "Appomattox" formation, describes the character and stratigraphic relations of the Columbia formation as follows:

"In North Carolina the relations displayed in the District of Columbia are maintained, save that the interfluvial phase becomes progressively more and more sandy in crossing the State from north to south, and finally passes into the essentially continuous veneer of sandy loam or fine sand completely cover-

[1]Report of the Geology of North Carolina, vol. 1, 1875, pp. 8-9, 12-19, 118-120, 153-161.

[2]The geology of Hatteras and the neighboring coast. (Abstract) Washington Phil. Soc., Bull., vol. 6, 1883, pp. 28-30.

[3]Elisha Mitchell Sci. Soc., Jour., 1884-85, pp. 92-93, 1885.

[4]Amer. Jour. Sci., 3d ser., vol. 35, 1888. Columbia formation, pp. 367-388, 448-466.

[5]Amer. Jour. Sci., 3d ser., vol. 40, 1890, pp. 15-41.

ing the seaward portion of the Coastal Plain from the Neuse River to Mobile Bay" (p. 17) . . . " in North Carolina and Virginia the Columbia is little more than a flowing mantle masking the more rugged framework of the older Appomattox" (p. 32).

In 1898[6] Lewis Woolman described the occurrence of fossil mollusks and diatoms in materials dredged from the bottom of the Dismal Swamp Canal and gave lists of the forms determined. He concludes that the deposits from which they were obtained are either of late Pliocene or early Pleistocene age. These beds are now referred to the Pleistocene.

In their text-book which appeared in 1906, T. C. Chamberlin and R. D. Salisbury[7] expressed the view that the Lafayette and Columbia formations of the Atlantic Coastal Plain were largely of fluviatile and subaërial origin. According to their interpretation, the deposits were laid down on flat peneplaned surfaces bordering the coast. Streams flowing from higher bowed-up regions to the west were unable to carry their load of sediments across this flat region, and consequently deposited them in the form of flood plain or broad alluvial fan accumulations. Those deposited farthest inland, owing to later elevation brought about by continued bowing up of the region to the west, may have been picked up again by the rejuvenated streams and carried forward and redeposited nearer the coast, and this process may have been repeated a number of times. This view is directly the opposite of that held by Dr. G. B. Shattuck,[8] who regards the surficial deposits of the Coastal Plain as having originated chiefly as marine and estuarine terrace deposits.

A monographic study of the Pliocene and Pleistocene deposits of Maryland by Dr. G. B. Shattuck[9] appeared in 1906. His conclusions regarding the nature and origin of these deposits will be referred to later in this report. The classification which he proposed is as follows:

Pliocene period:
Lafayette formation.
Pleistocene period:
Columbia group—
Sunderland formation.
Wicomico formation.
Talbot formation.

[6]Acad. Nat. Sci., Proc., 1898, pp. 414-428.
[7]Geology, vol. 3, 1906. Lafayette, pp. 301-308; Columbia, pp. 447-454.
[8]Johns Hopkins Univ. Circular, No. 152, May-June, 1901, pp. 69-75; Amer. Geol., vol. 28, 1901. pp. 87-107.
Pliocene and Pleistocene deposits of Maryland. Maryland Geol. Survey, 1906, 237 pages, plates 75.
[9]Op. cit.

In the same year the Maryland classification as proposed by Shattuck was adopted by Prof. William B. Clark and Dr. B. L. Miller[10] for equivalent deposits in Virginia.

The first investigator to recognize, in the surface features of the North Carolina Coastal Plain, a system of Pleistocene terracing similar to that displayed in the Maryland Coastal Plain was B. L. Johnson of the U. S. Geological Survey.[11]

The nature of the terracing in the Atlantic Coastal Plain region is such that, while it is possible in many places to recognize terraces, it is practically impossible, without the aid of contour maps, to trace any given terrace from one river valley to another. Early investigators had been so hampered by lack of maps showing details of surface configuration that they had failed to recognize the existence of the extensive system of ocean-facing terraces, and, consequently, did not grasp the true nature of the processes which had operated to produce them. The completion of a set of contour maps, covering practically all the Maryland Coastal Plain, enabled Dr. Shattuck to work out, in great detail, the system of terracing as exhibited in that State.

During recent years a set of these maps has been completed covering areas in eastern North Carolina in the vicinity of Tar and Neuse rivers, and extending from tidewater to the Piedmont border. In 1907 Johnson, with the aid of these maps, was able to recognize a number of ocean-facing terrace plains paralleling the coast, each successively older one occupying a position higher and more remote from the coast than the preceding. Reëntrants from each of the main terraces extend up the river valleys toward the Piedmont border. The several terrace plains are separated from each other by escarpments more or less well defined. The levels at which these plains occur, beginning with the youngest, are given as follows: The first varies in elevation from sea level to 20 or 25 feet above sea level; the second, from 30 to 50 feet; the third, from 60 to 80 feet; the fourth, from 110 to 140 feet; the fifth, from 180 to 200 feet, and remnants of terraces are noted at from 220 to 260 feet and at from 280 to 320 feet. The author's only statement regarding the correlation of these terraces is quoted as follows:

> "Terraces at these same elevations appear on topographic maps in Virginia and Maryland."

In 1907 E. W. Berry[12] announced the discovery of two Pleistocene plant localities in North Carolina, one on the Roanoke and the other

[10] Geol. Surv. of Virginia. Geol. Series, Bull. No. 2, 1906, pp. 21-24.
[11] Science, n. s., vol. 26, 1907, pp. 640-642.
[12] Jour. of Geol., vol. 15, 1907, pp. 338-349.

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

PLEISTOCENE.

COLUMBIA GROUP.

COHARIE FORMATION.

Name.—The name Coharie is derived from Great Coharie Creek, a tributary of Black River in North Carolina. The appropriateness of its application is suggested by the fact that the terrace plain formed by the surface of the deposits of the formation has a widespread development on either side of the narrow valley of this creek in the northern half of Sampson County. (See Great Coharie quadrangle.)

Definition.—The deposits referred to this formation constitute a terrace covering present over considerable areas, including the central part of Nash County, the western part of Wilson County, portions of eastern and southern Johnston County, southwestern Wayne County, the northern half of Sampson County, and a small area in eastern Harnett County, and south of Cape Fear River broad areas in southern Cumberland, northern Robeson, and southeastern Scotland counties. In the areas south of Cape Fear River the Coharie Plain has not been differentiated, except approximately, from the next lower-lying or Sunderland plain. All of these areas, except as they have been dissected by streams, present broad, almost level or very gently sloping surfaces. Broad reëntrants from the terrace plain of the lower-lying Sunderland formation extend up the principal valleys which have their courses across these areas. (See geologic map, Plate XIII, in pocket.)

Northward of the areas above described a narrow area of Coharie deposits is believed to extend through Halifax County and possibly through Northampton County into Virginia, but its limits have not been accurately determined. The Coharie plain extends southward into South Carolina, but the extent of its development in that State has not been determined.

Along the northwestern border of the Coharie belt as a whole the deposits are limited by the escarpment previously described as forming the southwestern boundary of the Lafayette belt. To the southeast they are limited by a sea-facing escarpment which separates them from the next lower lying, and younger, terrace formation, the Sunderland. This latter escarpment is well marked on the Rocky Mount and Kenly quadrangles. Outside of these quadrangles the escarpment has not been traced in detail, and the lines are drawn approximately, using railroad elevations and such other data as are available. Broad reëntrants from the Sunderland plain extend up the streams, and, in the case of some of the larger rivers, reach almost across the Coharie belt.

[illegible] Neuse River. [illegible] In [illegible] are flat. [illegible] have been [illegible] City, N. J., and a

A.—Flattened pebbles from the beach at Atlantic City, N. J.

B.—Flattened pebbles from the beach at Ocean City, N. J.

(These illustrations are introduced for the purpose of comparison with pebbles from Four Oaks, N. C., shown on Plate XVIII.)

Flattened pebbles from the Coharie formation, 1½ miles southeast of Four Oaks, Johnston County, N. C.

striking similarity in shape is apparent. This fact is believed to have a significant bearing on the question of the origin of the materials. (See Plate XVI, A and B, and Plate XVIII, opposite p. 274.)

Locally the gravels in this formation have been cemented by iron to form a conglomerate.

With the exception of small pieces of silicified wood in the deposits forming the tops of the hills west of Fayetteville and a few trunks of silicified trees in similar deposits near Wade, both in Cumberland County, and one fragment of silicified wood from a cut 3½ miles southwest of Four Oaks, no fossil remains have been obtained from the beds of this formation.

The thickness of the deposits probably averages about 25 feet, being less in places, and in places more, perhaps reaching a maximum of 40 or 50 feet locally.

Detailed Sections.—Some of the best exposures of the Coharie formation occur in Johnston County, especially in railroad cuts in the vicinity of Four Oaks. In a cut 2¾ miles northeast of the station, near Corinth Church (see Four Oaks quadrangle) the Coharie beds are seen to rest unconformably upon the Patuxent formation. (See Fig. 3, p. 94, and Plate XX, A, opposite p. 277.) The materials consist, first, of 0 to 2 feet of loose, gray, coarse, pebbly sand, forming a surface mantle, and, second, of 4 to 8 feet of mottled, coarse, argillaceous sand, with scattered pebbles and thin lenses and layers of pebbles in places. The contact with the underlying Patuxent formation is sharp and easily traceable. Another good section is afforded by a cut 5 miles southwest of Four Oaks. Here the Coharie materials consist of coarse, yellow, argillaceous, pebbly sand, with irregular lenses of pebbles which are more numerous along the base. Many of the pebbles and cobbles are smoothly rounded and they reach maximum diameters of 3 or 4 inches.

In the region to the southeast, south, and southwest of Four Oaks, the gravels of the Coharie contain noticeable percentages of flat, smoothly rounded pebbles. (See Plate XVIII, opposite.) Mention may be made of gravel occurrences in the vicinity of the first crossroads 1½ miles directly southeast of Four Oaks, where this feature is especially noticeable. The same may be said of a gravel bed exposed in a cut of the Smithfield and Fayetteville road about 6 miles south of Four Oaks, where the road passes up the south slope of Stone Creek. (See Four Oaks quadrangle.) The section exposed here is described as follows:

SECTION IN SMITHFIELD AND FAYETTEVILLE ROAD, 6 MILES SOUTH OF FOUR OAKS ON SOUTH SLOPE OF STONE CREEK.

	Feet.
Pleistocene (Coharie formation):	
Coarse, loose, gray sand	1 to 3
Coarse, yellow, argillaceous sand	2 to 3
Gravel bed with mottled, argillaceous sand matrix. Large percentage of the pebbles smoothly rounded and many of them flat, probably as the result of wave action on a beach	6 to 7
(Unconformity.)	
Cretaceous (Patuxent formation):	
Dark drab clay	8
Light gray, compact, argillaceous sand	20

The Coharie plain has an extensive development to the west of Fayetteville in Cumberland County. It here lies about 100 feet above the plain on which the business part of the town stands, the latter being about 100 feet above sea level and probably representing the Wicomico plain. There are a few poor exposures of the Coharie materials along the crest of the scarp separating these two plains, and from these the following section is constructed:

SECTION CONSTRUCTED FROM EXPOSURES IN THE STREETS ALONG THE WESTERN EDGE OF FAYETTEVILLE, N. C.

	Feet.
Pleistocene (Coharie formation):	
Yellow, red, and mottled coarse sand, with a band of pebbles, for the most part smoothly rounded along base	30
(Unconformity.)	
Cretaceous:	
Black Creek formation:	
Drab clay and yellow sand poorly exposed	30
(Unconformity.)	
Patuxent formation:	
Coarse, gray, arkosic sands and drab clays (to level of tracks at station)	40

The road running west from Fayetteville to Aberdeen passes over the Coharie plain a distance of 11 or 12 miles before it enters the sandhills which mark the western limit of the Coharie formation in this region. A road-cut 8 or 9 miles from Fayetteville exposes the following section:

SECTION IN ROAD-CUT, FAYETTEVILLE AND ABERDEEN ROAD, 8 OR 9 MILES WEST OF FAYETTEVILLE, N. C.

	Feet.
Pleistocene (Coharie formation):	
Loose gray sand	2
Coarse, yellow, somewhat pebbly argillaceous sand	8

A.—Coharie terrace plain, looking northward, along the Atlantic Coast Line Railroad, one mile south of Bules, Robeson County, N. C

B.—Exposure of the Coharie formation resting unconformably upon the Patuxent formation; cut of Atlantic Coast Line Railroad, five miles southwest of Four Oaks, Johnston County, N. C.

A.—Exposure of the Coharie formation resting unconformably upon the Patuxent formation, cut of the Atlantic Coast Line Railroad, 2¾ miles northeast of Four Oaks, near Corinth Church, Johnston County, N. C.

B.—Gravel layer in sand of the Coharie formation; cut of the Atlantic Coast Line Railroad, one mile northeast of Four Oaks, Johnston County, N C.

	FEET.
Gravel bed with matrix similar to preceding material. Pebbles for the most part smoothly rounded and averaging less than 1 inch in diameter with maximum of 2 inches. Many of the pebbles flat	5
(Unconformity.)	
Cretaceous (Patuxent formation):	
Drab clay with fine white sand partings........................	3

Good exposures showing the Coharie formation resting directly upon basement rocks may be seen in eastern Johnston County, especially in railroad cuts in the vicinity of Kenly, and in Nash County, especially in railroad cuts in the vicinity of Nashville. (See Plate XXI, A, opposite p. 278.)

SUNDERLAND FORMATION.

Name.—The name Sunderland is derived from the village of Sunderland in Calvert County, Md., and was proposed as a formation name by Dr. George B. Shattuck in 1901.[1]

Definition.—The materials of this formation constitute a terrace deposit which occupies a position lower than that of the above-described Coharie formation. The area covered by them includes portions of Northampton, Halifax, Nash, Edgecombe, Wilson, Wayne, Johnston, Duplin, Sampson, Cumberland, Bladen, Robeson, and Columbus counties. The area as a whole forms a belt varying in width from 5 or 10 miles near the Virginia line to more than 30 miles along the South Carolina line. The belt extends into South Carolina, but its limits there have not been even approximately determined. (See geologic map, Plate XIII, in pocket.)

The formation is limited on the northwest by the sea-facing escarpment previously described as determining the southeastern border of the Coharie formation. On the southeast the Sunderland belt is separated from the next lower-lying terrace plain, the Wicomico, by an escarpment more or less well defined. This escarpment is easily traceable on the Tarboro and Falkland quadrangles. Outside of these quadrangles its position is known in most places only approximately.

Reëntrants from the next lower lying or Wicomico terrace plain extend up the valleys of the principal streams in some instances entirely across the Sunderland belt, and along these reëntrants the Sunderland plain is separated from the Wicomico plain by well-defined escarpments.

The Sunderland formation rests, as an unconformable terrace covering, upon the beds of various older Coastal Plain formations, and,

[1] Johns Hopkins University Circular, No. 152, May-June, 1901, pp. 69-75.

in part, upon basement rocks. In the north, in Wilson, Nash, and Halifax counties, the latter relations are exhibited along the western edge of the area. In this same region the remaining part of the area is underlain by Miocene beds. From the Neuse River Valley southward the subjacent materials are, for the most part, of Cretaceous age, belonging in part to the Patuxent formation, in part to the Black Creek formation, and in part to the Peedee formation. There are, however, limited areas of subjacent Eocene and Miocene beds. The upper surface of the formation constitutes a nearly level plain which slopes from an elevation of about 110 feet above sea level, near the edge of the escarpment which forms its southeastern boundary, to elevations of from 140 to 150 feet along the base of the escarpment separating it from the Coharie formation.

Around the outer edges of the terrace and along the sides of the valleys crossing it this plain has been considerably dissected by stream erosion, but the interstream areas present broad stretches of nearly level plain.

What has been said regarding the lithologic character of the materials of the Coharie formation will apply in all essential respects to those of the Sunderland formation, except that the sands, loams, and gravels of the latter are perhaps in general finer than those of the former.

The average thickness of this formation is also believed to be about the same as that of the Coharie formation, that is, 20 or 25 feet, although in places this amount is probably exceeded by a number of feet.

Detailed Sections.—Many shallow exposures occur throughout the area covered by the Sunderland terrace, particularly in railroad and road-cuts, but as a rule the incisions are not deep enough to reveal the base of the formation. At a few places, however, its contact with underlying beds has been observed. An exposure in which this relation is clearly shown occurs in a road-cut 5 miles south of Rocky Mount and 1 mile east of the Atlantic Coast Line Railroad track in Edgecombe County. The section is given below:

SECTION IN ROAD-CUT 5 MILES SOUTH OF ROCKY MOUNT, N. C.

	Feet.
Pleistocene (Sunderland formation):	
Yellow, coarsely arenaceous clay, grading down into material below	5
Extremely coarse, yellow and gray argillaceous sand, with scattered, angular, quartz pebbles up to ½ inch in diameter, the latter more abundant towards base. Contains, also, near base, numerous small clay balls reworked from underlying clay	10
(Unconformity.)	

Photo by B. L. Johnson.

A.—Exposure of the Coharie formation resting unconformably upon decomposed basement slate; cut of the Atlantic Coast Line Railroad, Nashville, Nash County, N. C.

B.—Sunderland terrace plain, six miles south of Rocky Mount, N. C., in Edgecombe County, near the Wilson County line.

A.—Sunderland terrace plain, Nash Street, in the southeastern part of Wilson, N. C., looking northwestward.

B.—Sunderland terrace plain, Atlantic Coast Line Railroad yards, South Rocky Mount, N. C.

Miocene:	FEET.
Yellow, finely laminated clay..................................	4

On Cape Fear River the Pleistocene deposits exposed at the tops of the high bluffs, at Prospect Hall, Court House Landing, and Walker's Bluff, are believed to represent this formation. (See pp. 116, 118, 121.) The Pleistocene materials at the top of the bluff known as "The Cliffs" on Neuse River, 1½ miles above Seven Springs in Wayne County, also probably belong to this formation (p. 134).

WICOMICO FORMATION.

Name.—The name Wicomico is derived from the river of that name in Charles and St. Marys counties, Maryland, where the formation is well developed. It was first proposed by Dr. G. B. Shattuck[1] in 1901.

Definition.—The Wicomico formation has been traced as a well-defined terrace from Maryland, where it was first differentiated and named, through Virginia and North Carolina. In North Carolina it appears as a surficial terrace deposit in a belt lying to the southeast of that of the Sunderland formation and extending from the Virginia line to the South Carolina line. But little is known of the southward extension of the formation into South Carolina. The average width of the terrace in North Carolina is between 25 and 30 miles, although in places it is somewhat wider and elsewhere narrower. Reëntrants from the formation extend up the valleys of all the principal rivers as bordering terrace deposits several miles in width, in places entirely across the Sunderland belt. The western boundary of the main Wicomico belt as a whole is formed by the seaward-facing escarpment previously described as limiting the Sunderland belt on the southeast. As before stated, this escarpment has been traced in detail only within the limits of the Falkland and Tarboro quadrangles. Elsewhere its position is known only approximately, and in all probability it is very obscure at many places. The estuarine extensions which border the rivers are in most places separated from the higher Sunderland plain by sharply defined escarpments. On the southeast the Wicomico terrace is limited by an ocean-facing slope or escarpment which has been traced with approximate accuracy on the New Bern, Vanceboro, Chocowinity, Williamston, Edenton, and Beckford quadrangles. In places it is well defined, but elsewhere the plain grades down rather gradually into the next lower or Chowan Plain. Outside of these quadrangles the boundary has been traced only approximately. Wide reëntrants from the

[1]Johns Hopkins Univ. Circular, No. 152, 1901, pp. 69-75; also Amer. Geol., vol. 28, 1901, pp. 67-107.

Chowan terrace extend up the river valleys, in places almost entirely across the Wicomico belt. These estuarine plains are in most places separated from the Wicomico plain by well-defined escarpments. Numerous clean-cut sections of the formation are exhibited in the bluffs of all the larger streams where they cross the area of its occurrence. (See geologic map, Plate XIII, in pocket.)

In position the formation rests unconformably upon older deposits of the Coastal Plain. North of Neuse River these consist for the most part of Miocene beds, but in part, especially beneath the estuarine extensions, of Cretaceous beds. South of Neuse River it rests in part upon Miocene, in part upon Eocene, and in part upon Cretaceous beds. Its upper surface forms a terrace plain which in the main belt slopes up from elevations of about 50 feet along the southeast edge of the area to about 90 or 100 feet along the foot of the seaward-facing escarpment which separates it from the plain above. The reëntrants which extend up the river valleys slope up to elevations exceeding 100 feet above sea level at their inland extremities.

The plain has been somewhat dissected by stream erosion, more especially along the borders of the valleys and along the escarpments, but in general the valley incisions are much shallower than in the case of the older terrace plains. Broad, level stretches exist in the interstream areas, and some of these form extensive areas of swamp land, locally termed pocosons, savannahs, and bays.[2] The larger of these swamps are Angola Bay in Duplin and Pender counties, Holly Shelter Swamp in Pender County, Great Dover Swamp in Craven and Jones counties, and Whiteoak Pocoson in Jones County.

In lithologic character the formation consists of sandy clays, sands and gravels, resembling in a general way those of the Coharie and Sunderland formations. In nearly all sections the coarser sands, or sands and gravels, form the basal beds, and, as a rule, show stratification and cross-bedding. These grade upward into finer sands and sandy clays of uniform texture. Along nearly all the rivers crossing the belt which have their source inland in the Piedmont Plateau region, the exposures reveal near the base of the Wicomico deposits numerous erratic bowlders of quartz and various kinds of crystalline rocks which are in

[2] *Pocoson.*—A tract of level wet land supporting a thick growth of gums, gall berries, bay bushes and trees, and other bushes, trees, etc., which prefer a wet soil.

Savannah.—A tract of level land having a wet soil except during periods of dry weather, and supporting grass and other low vegetation, with but a scattered growth of pine or other trees and bushes, so that a horse or other object of similar size may be seen at a distance of ½ to 1 mile. Sometimes applied to tracts of open prairie land.

Bay.—A flat or slightly depressed tract of greater or less extent, with either wet or dry soil, supporting a conspicuous growth of bay trees and bushes.

A.—Sunderland terrace plain, street in Lumberton, Robeson County, N. C.

B.—Exposure showing the Wicomico formation resting unconformably upon Miocene strata, Old Sparta-Pinetops road, one mile south of Old Sparta, Edgecombe County, N. C.

some instances quite large, attaining maximum dimensions of 4 or 5 feet. These are believed to have been transported from the Piedmont region by floating ice, or in the roots of floating trees.

The thickness of the formation varies from 10 to 30 feet, or perhaps in rare instances amounting to as much as 40 feet or more. The average probably lies between 20 and 25 feet.

With the exception of fossils which have been reworked from older underlying formations, no animal remains have been found in the deposits of the formation. Fossil leaves have been found at one locality near Weldon which is believed to represent an estuarine phase of the formation.

Detailed Sections.—There are many exposures of this formation in the bluffs of the larger rivers crossing the belt, and occasional exposures along smaller streams and in road and railroad cuts. In almost all cases the beds form the upper 10, 15, or 20 feet of the section, and rest unconformably upon strata of pre-Pleistocene age, either Tertiary or Cretaceous. A few localities will be described in detail on following pages.

As above noted, fossil leaves were obtained near Weldon. The locality is 1¼ miles east of the village, a short distance directly east of the wagon bridge over Roanoke River in Northampton County. From poor exposures the following section was prepared:

SECTION 1¼ MILES EAST OF WELDON, NORTHAMPTON COUNTY, N. C.

Pleistocene (Wicomico formation):	FEET.
Mostly concealed by vegetation, but in part yellow, more or less sandy clay	35
Yellow, pebbly, argillaceous sand	2
Small lens of yellow, sticky clay, containing well-preserved prints of leaves	½
Yellow, very coarse, pebbly, arkosic sand. The pebbles are for the most part only partially water-worn	2½

The following list is furnished by E. W. Berry, to whom the fossil plants from the above locality were sent for identification (see, also, Torreya, vol. 9, No. 4, April, 1909):

Cercis canadensis Linné.
Liriodendron tulipefera Linné.
Quercus predigitata Berry.
Quercus sp.

The top of the section as determined by aneroid readings is about 95 feet above sea level, and the base is about 20 feet above the normal stage of water in Roanoke River. The deposit is regarded as an estua-

[illegible] near the [illegible] the [illegible]

[illegible] Halifax [illegible] It is described as fol-[illegible]

	Feet
[illegible]	[illegible]
[illegible]	
[illegible]	[illegible]
[illegible] fragments...	[illegible]
[illegible]	[illegible]

[illegible] unconformably upon [illegible]

[illegible] Banks Landing, Tar River, [illegible] Greenville in Pitt County, may be seen [illegible]

The following [illegible] 1 mile southwest of [illegible] quadrangle; see, also, Plate IX, B, [illegible]:

[illegible] COUNTY, N. C.

Pleistocene: W[illegible]: Feet

[illegible] yellow argil-[illegible] 8

Miocene:

[illegible] 17

CHOWAN FORMATION.

Name.—The name Chowan is derived from Chowan River, N. C., to the south of which in Hertford County the plain forming the surface of the formation is typically developed.

Definition.—The deposits of this formation cover a belt varying in width from a few miles to about 25 miles lying to the southeast of that described for the Wicomico formation, and extending interruptedly from Virginia to South Carolina. The northwestern extent of the main area of the formation is limited by the seaward-facing escarpment previously described as forming the southeastern boundary of the Wicomico terrace. However, wide reëntrants extend up all the larger rivers, in some instances reaching entirely across the area occupied by the Wicomico deposits. (See geologic map, Plate XIII, in pocket.)

The eastern boundary is marked by a well-defined sea-facing escarpment which separates the Chowan terrace plain from the lower-lying

A.—Chowan terrace plain, looking northward, two miles northeast of Old Sparta on Tarboro-Penny Hill road, Edgecombe County, N. C.

B.—Pocosin land (see the definition, footnote, page 280) on Wicomico terrace plain, Castoria-Farmville road, 1½ miles northeast of Castoria, Falkland quadrangle, N. C.

Pamlico terrace plain. This escarpment enters North Carolina from Virginia in the eastern part of Gates County (see Beckford and Edenton quadrangles), and runs in a nearly straight line a little west of south until it intercepts the coast in the western part of Carteret County. Its position outside of the areas covered by topographic maps is known only approximately for the greater part of the distance; however, Mr. B. L. Johnson has observed the escarpment a short distance to the eastward of the towns of Grantsboro and Arapahoe in Pamlico County. Along the crest of this escarpment throughout much of its extent are accumulations of wind-blown sand in the form of narrow ridges which probably originated at the time the shore line stood at the foot of the escarpment's slope. Reëntrants from the Pamlico plain extend up the river valleys for many miles as bordering terraces. In many places the Chowan plain is separated from these estuarine extensions by well-marked escarpments. Southward of Carteret County the Chowan plain extends nearly to the coast, being separated from the shore line by very narrow strips of the Pamlico terrace. The Chowan terrace plain, together with the escarpment separating it from the lower-lying Pamlico plain, has been traced northward through Virginia into Maryland.

North of Neuse River the materials of the Chowan formation rest for the most part upon beds of Miocene age. The estuarine extensions, however, occur far enough to the west to lap over upon Cretaceous beds. To the south of Neuse River the underlying deposits consist of Pliocene, Miocene, Eocene, and Cretaceous strata.

The surface of the formation forms a plain which slopes up from elevations of about 25 to 40 feet above sea level along its eastern edge to elevations of about 50 feet along the foot of the escarpment separating it from the Wicomico plain above. Where it passes up the river valleys, however, it probably reaches maximum elevations of 70 feet at the inland extremities of the extensions. In the interstream areas the plain presents broad, level tracts of land which are swampy in many places. Green Swamp in Columbus and Brunswick counties is believed to form a part of this plain. Waccamaw Lake in Columbus County probably occupies a shallow depression in the plain. Around the edges the plain has been dissected to some extent by stream erosion forming shallow stream incisions.

The materials making up the Chowan formation consist of sandy loams, more or less arenaceous clays, sands, and gravels. As in the case of the Pleistocene formations already described, the coarser materials occur at the base and grade up into the finer sands and loams at the top. In general, the materials are finer in texture than those of the

older Pleistocene deposits. Erratic bowlders of quartz and crystalline rock occur in the basal beds of the formation along the immediate river borders. These have been especially noted along Roanoke River from Halifax southward to Palmyra. At Big Rocky Bar, about 20 miles below Halifax, one such bowlder was observed whose dimensions were roughly stated 7 by 3 by 2 feet.

The formation is relatively thin, perhaps averaging 15 or 20 feet. The greatest measured thickness occurs along the west bank of Cape Fear River in the vicinity of Old Brunswick in Brunswick County. Here the bluffs, which range from 15 to 35 feet in height, are made up entirely of Chowan beds, no older strata appearing above tide level.

Fossil remains are rare in the beds of this formation, but both plants and invertebrates have been found at a few places.

Detailed Sections.—Many exposures of the beds of the Chowan formation occur in the bluffs of the streams crossing the belt. Along the western shore of the Cape Fear River estuary between Southport and the ruins of Old Brunswick in Brunswick County, a series of bluffs affords good opportunities for studying the deposits. Two sections presenting features of special interest are included below:

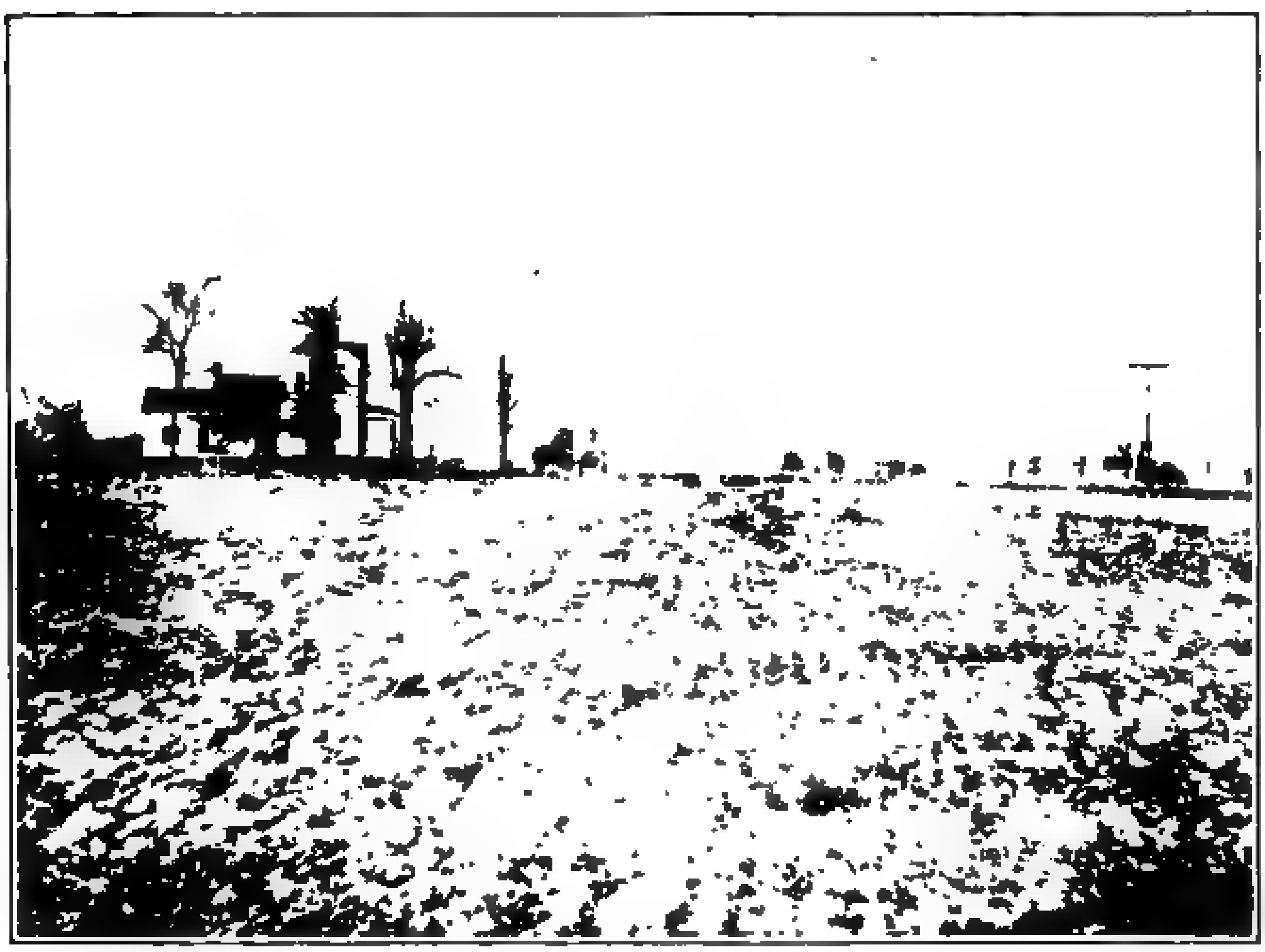
SECTION ON CAPE FEAR RIVER ½ MILE NORTH OF THE RUINS OF OLD BRUNSWICK, BRUNSWICK COUNTY.

Pleistocene (Chowan formation):	FEET
Sandy, loamy soil	1
Fine, loose, light yellow sand	6
Hard, yellow, somewhat argillaceous sand, with small, tubular, iron concretions and small sand concretions cemented with iron	½
Light drab, somewhat arenaceous, finely micaceous clay, mottled with pink, red and yellow	2
Coarse, reddish brown sand, with lenses of drab clay and lenses of oyster shells. The oysters belong to the living species *Ostrea virginica* Linné. A few specimens of *Venericardia tridentata* Say, are found associated with the oysters	2
Coarse, cross-bedded, yellowish-brown and black sands	2

SECTION ON CAPE FEAR RIVER, ½ MILE ABOVE THE MOUTH OF PRICE CREEK AND ABOUT 2 MILES NORTH OF SOUTHPORT, BRUNSWICK COUNTY.

Pleistocene (Chowan formation):	FEET.
Light yellow, medium-grained sand	2½
Dark, sandy loam, resembling an old soil	½
Loose, light yellow and gray sands	3½
Loose, yellow, coarse-grained sand	3
Light gray, arenaceous clay, mottled with pink and yellow	3
Loose, light, slightly micaceous, stratified sand, streaked and mottled with yellow	10
Concealed	7

A.—Exposure of the Chowan formation, west shore of Cape Fear River, about two miles north of Southport, and one-quarter of a mile above the mouth of Price Creek, Brunswick County, N. C.



B.—Chowan terrace plain, looking northward, one mile northeast of Old Sparta, Edgecombe County, N. C.

	Feet.
Bright yellow and pink clay	½
Dark, bluish or drab, sandy clay, becoming more sandy toward base, contains impressions of fossil shells	1
Light, coarse sand, mottled with yellow	½
Concealed by beach sand	1½
Dark to black clay and sand containing a large amount of brown lignite in the form of twigs, limbs and trunks, etc. This layer exposed only at low tide	1

At one locality on Neuse River which is questionably referred to the Chowan formation a large accumulation of fossil leaves, nuts, and other plant remains has been preserved. Collections of these have been studied by E. W. Berry.[1] This deposit is believed to have been formed near the head of an estuary. The details of this section are given below:

SECTION ON NEUSE RIVER, 79¾ MILES ABOVE NEW BERN AND ABOUT 4½ MILES ABOVE SEVEN SPRINGS, RIGHT BANK.

Pleistocene (Chowan formation?):	Feet.
Clay loam, grading down into sandy loam	4
Coarse white and yellow sand with gravel layers toward base; some bowlders of crystalline rock in lower portion	7
Tough blue clay with interstratified laminæ and layers up to 2 or 3 inches in thickness consisting of masses of well-preserved leaves with some lignitized wood, acorns, hickory nuts, beech nuts, etc.	3

The section is formed where the river cuts against the edge of a very level stream-bordering terrace. On account of the lack of topographic maps, it is impossible to determine with certainty the proper correlation of this deposit, but the evidence seems to favor the interpretation here adopted.

E. W. Berry refers to the above locality as Station 850, Neuse River. He has identified the following forms:

STATION 850, NEUSE RIVER.

Pinus rigida Mill (leaves).
Taxodium distichum (L.) Rich (foliage).
Hicoria ovata (Mill) Britt (leaves and nuts).
Hicoria glabra (Mill) Britt (leaves).
Hicoria aquatica (Michx. f.) Britt (leaves).
Salix sp., No. 1 (leaves).
Salix sp., No. 2 (leaves).
Carpinus caroliniana Walt. (leaves).
Betula nigra Linné (leaves).
Betula pseudofontinalis Berry (leaves).
Fagus americana Sweet (leaves and fruit).
Quercus platanoides (Lam.) Sudw.? (leaves).
Quercus prinus Linné (leaves).

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[1] Jour. of Geol., vol. 15, 1907, pp. 338-349.

Quercus nigra Linné (leaves).
Quercus marylandica Muench? (leaves).
Quercus palustris Du Roi (leaves).
Quercus alba Linné (leaves).
Quercus lyrata Walt. (leaves).
Quercus phellos Linné (leaves and acorns).
Quercus michauxii Nutt. (leaves and acorns).
Quercus predigitata Berry (leaves).
Quercus abnormalis Berry (leaves).
Quercus sp. (cupules).
Quercus sp. (leaves).
Ulmus alata Michx. (leaves).
Planera aquatica (Walt.) ? (leaves).
Liquidambar styraciflua Linné (leaves and fruit).
Platanus occidentalis Linné (leaves and fruit).
Rubus sp. (twigs).
Malus pseudo-angustifolia Berry (leaves).
Malus cprinariafolia Berry (leaves).
Crataegus spathulatoides Berry (leaves).
Crataegus coccineafolia Berry (leaves).
Ilex opaca Ait. (leaves).
Vitis sp. (tendrils).
Persea pubescens (Pursh) Sargent (leaves).
Nyssa biflora Walt. (leaves).
Xolisma ligustrina (Linné) Britt. (leaves).
Dendrium pleistocenicum Berry (leaves).
Vaccinium corymbosum Linné (leaves).
Vaccinium spatulata Berry (leaves).
Vaccinium arboreum Marsh. (leaves).

On Tar River, at Dupree Landing, about 14 miles above Greenville, Falkland quadrangle, an exposure occurs as described in the section given below:

SECTION AT DUPREE LANDING, TAR RIVER, RIGHT BANK.

	Feet.
Pleistocene (Chowan formation):	
Sandy loam and argillaceous sand with pebbles along base.......	6
Lignite bed consisting of a mass of logs, twigs, leaves, acorns, etc., in the form of lignite. Fills a depression in the underlying Patuxent formation	0-3
(Unconformity.)	
Lower Cretaceous (Patuxent formation):	
Compact sands and clays.................................	6

From the lignite bed above described E. W. Berry identified cones of *Pinus rigida* Mill, and acorns of *Quercus phellos* Linné.

PAMLICO FORMATION.

Name.—The name Pamlico is derived from Pamlico Sound in eastern North Carolina, away from whose shores the terrace plain forming the surface extends as broad, nearly level, stretches of lowland. The plain is also present on either side of Pamlico River and covers the greater part of Pamlico County.

Definition.—The materials of this formation cover all of that part of the State lying to the east of the escarpment which separates it from the Chowan formation. Reëntrants extend for many miles up the

Photo by B. L. Johnson.

A.—Exposure of the Pamlico formation, near the pier of the Norfolk Southern Railroad, Oriental, Pamlico County, N. C.

B.—Exposure showing 2½ feet of loose white sand resting on loose pale yellow sand, on Chowan terrace plain; cut of Atlantic Coast Line Railroad, three-quarters of a mile southeast of Richards Station, Pender County, N. C.

principal river valleys. South of Carteret County the Pamlico formation has only a limited development, being present in places along the coast and along the valley sides as very narrow bordering terraces. (See geologic map, Plate XIII, in pocket.)

The Pamlico terrace has been traced northward through Virginia into Maryland.

The character and age of the strata underlying the deposits of this formation are but imperfectly known. It is certain, however, that they are in part of Eocene, in part of Miocene, and in part of Pliocene age. It is certain, also, that in parts of the area beds of shell marl of Pleistocene age occur at shallow depths beneath the surface. To which formations of the Pleistocene these should be referred, however, has not been determined with certainty.

The upper surface of the Pamlico beds forms a low, nearly level, plain whose elevation above sea level nowhere exceeds 25 feet. Much the greater part of the area is made up of vast tracts of swamp land of which the Great Dismal Swamp which extends into the State from Virginia is a typical example. Several lakes occupy shallow depressions in this plain. The largest of these is Mattamuskeet Lake in Hyde County. Others are Alligator Lake in the same county and Phelps and Pungo lakes in Washington County.

The Pamlico terrace plain, on account of its low elevation and also on account of the relatively short time since its elevation above sea level as compared with the older terrace plains, has been subjected to but a slight amount of stream erosion. It is, therefore, preëminently the best preserved of the several Columbia terrace plains.

The materials of this formation consist of fine sandy loams, sands and clays, and to a limited extent of gravels. In the swamp lands the soils consist in large part of accumulations of peaty matter, which are of later origin than the main body of the deposits.

The thickness of the deposits is slight, the beds which may be regarded as strictly of terrace origin probably in but few places exceeding 15 or 20 feet.

But little is known regarding the fossil contents of the deposits. It is certain that marine shell beds of Pleistocene age underlie portions of the area. It is possible that much of the region covered by the Pamlico beds was under water during parts of Pleistocene time preceding the deposition of the Pamlico material. In this case some of the Pleistocene shell beds occurring at shallow depths beneath the surface are in all probability older than the Pamlico formation.

Detailed Sections.—A good exposure showing several feet of sandy clay overlain by 1 foot of dark to black soil has been noted by B. L.

Johnson at the pier of the Norfolk Southern Railway at Oriental, Pamlico County. (See Plate XXVI, A, opposite p. 286.)

Plant remains from beds supposed to be from this formation are known at two localities. One of these is on Roanoke River, 8 miles above Williamston in Bertie County. The species found there have been listed by E. W. Berry.[1] The section is given in detail as follows:

SECTION, ROANOKE RIVER, OLD MILL LANDING, 8 MILES ABOVE WILLIAMSTON, LEFT BANK.

	Feet.	Inches.
Pleistocene (Pamlico formation):		
Surface loam grading down into gray and buff sand, containing small pebbles as large as peas, interstratified with argillaceous layers	10	
Layer of fine gravel	...	8-10
Concealed	3	6
Layer of fine gravel	1	
Cross-bedded, gray and yellow sand	1	
Bed of orange-colored gravel with sand matrix slightly indurated, the pebbles not exceeding 2 inches in diameter	...	6
Gray and orange, sandy, arenaceous clay, grading down into tough, drab clay	5	
Dark, micaceous clay, containing plant remains, the following of which have been identified: *Taxodium distichum* (Linné) Rich; *Betula nigra* Linné; *Nyssa biflora* Walt., and *Vaccinium corymbosum* Linné	0-1	

The other locality is on Neuse River 10 or 12 miles below New Bern, on the southwest bank, where Prof. J. A. Holmes[2] has described the occurrence of buried cypress stumps (*Taxodium distichum* (Linné) Rich.) in Quaternary deposits.

The localities previously referred to where marine Pleistocene fossils have been collected will be mentioned briefly here, since they occur geographically within the area covered by the Pamlico formation. It is possible, however, that some or all of them underlie the Pamlico beds unconformably, in which case they should be regarded as representing one of the older divisions of the Pleistocene.

At Old Fort Fisher, near the southern extremity of New Hanover County, a bed of coquina rock consisting almost entirely of fragments of shells, with a few nearly perfect ones, is exposed along the beach. From this Dr. T. Wayland Vaughan has collected and determined the following Pleistocene forms: *Fulgur carica, Ostrea virginica, Venus mercenaria, Rangia cuneata.* (See Plate XXVII, A.)

From a similar Pleistocene coquina bed 1 mile southeast of Carolina Beach wharf in southern New Hanover County, Dr. Vaughan also col-

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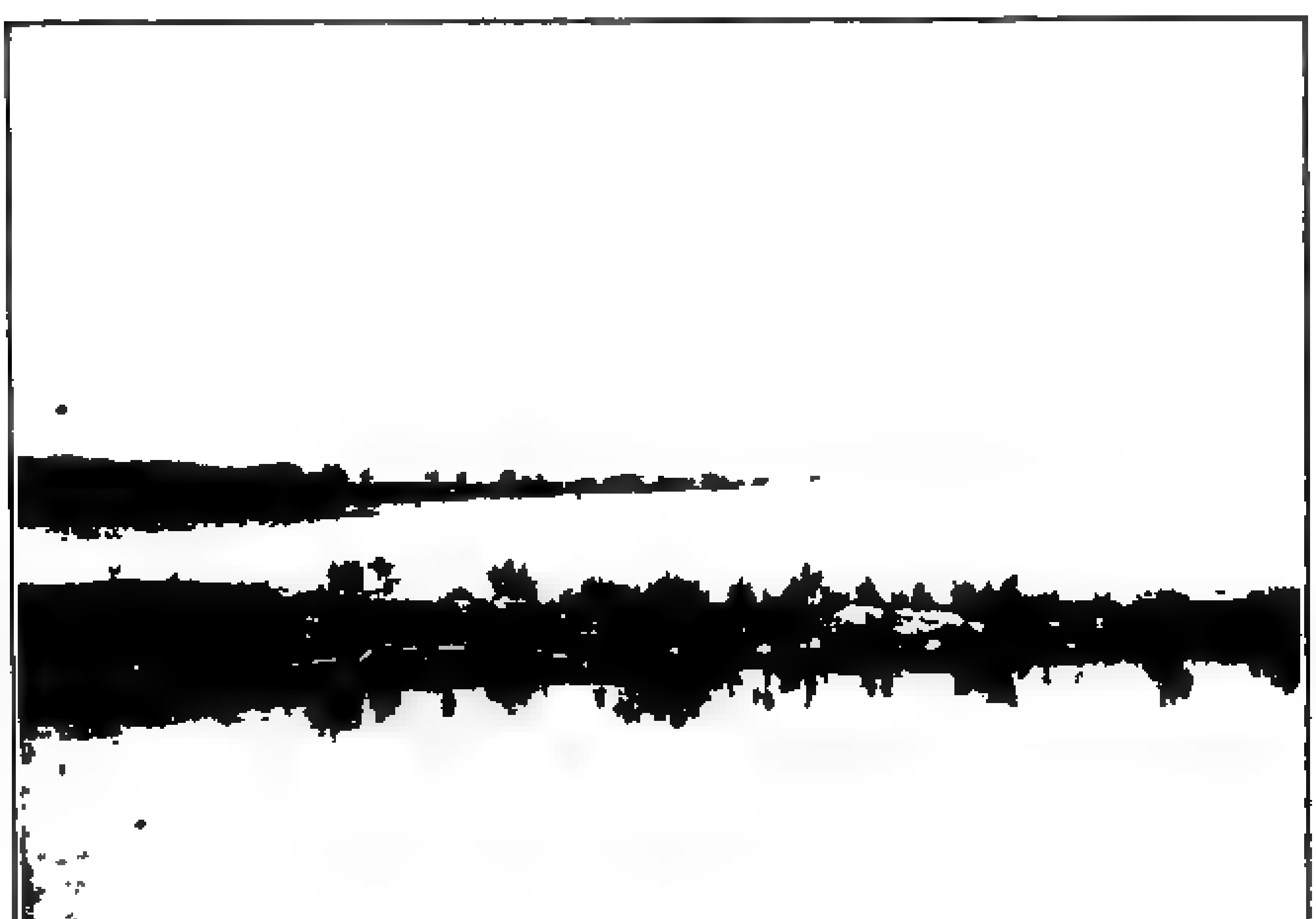
[1]Jour. of Geol., vol. 15, 1907, pp. 338-349.
[2]Elisha Mitchell Sci. Soc., Jour., 1884-85, pp. 92-93, 1885.

A.—Exposure of coquina rock of Pleistocene age, New Hanover County, N. C.



B.—Mattamuskeet Lake, Lake Landing, Hyde County, N. C.

lected and determined the following forms: *Arca ponderosa, Arca pexata, Ostrea virginica, Venus mercenaria, Rangia cuneata* and *Spisula solidissima.*

Well borings from the Pleistocene portion of the section at the Quarantine Station, near Southport, furnished the following mulluscan forms, identified by E. W. Berry (see well section, p. 168):

Membranipora sp.	*Dentalium* sp.
Echinoid spines.	*Polynices duplicatus* (Say).
Scutella sp.	*Crepidula fornicata* (Linné) Lam.
Leda acuta (Conrad).	*Crepidula plana* Say.
Yoldia limatula Say.	*Turbonilla interrupta?*
Nucula proxima Say.	*Turbonilla reticulata?*
Pecten sp. (young).	*Scala multistriata* Say.
Venus sp. indet.	*Nassa trivittata* Say.
Tellina sp.	*Tornatina canaliculata* (Say).
Cumingia tellinoides (Conrad).	*Columbella lunata* (Say).
Donax sp.	Crab claws.
Ensis directus (Conrad).	*Drillia* sp.
Corbula contracta Say.	*Glyphostoma* sp.
Mulinia lateralis Say.	*Balanus crenatus* Brug.
Mulinia transversa Say.	

From borings obtained from the upper part of the deep well at Fort Caswell the following forms were obtained:

Teredo sp.	*Crepidula fornicata* (Linné) Lam.
Scutella sp.	*Cardium* sp.
Ostrea virginica Linné.	*Barnea costata* (Linné) Lam.

In 1835 H. B. Croom[1] described a fossil locality on the north bank of Neuse River, 16 miles below New Bern, on the estate of Lucas Benners, at which were obtained the vertebrate remains of a large number of sea and land animals and a great variety of sea shells. The shell remains from this locality were identified and listed the same year by T. A. Conrad.[2] Of sixty-seven species recognized, five were new, eight were living on the coasts of Florida and the Gulf of Mexico, and the remainder inhabited the coast of the Middle and Southern States. He referred the deposit to the "Newer Pliocene."

A second list from this same locality was given by Conrad[3] in 1842. He here refers the deposit to the post-Pliocene or the upper Tertiary formation. The large percentage of recent forms enumerated in both lists indicates the Pleistocene age of the bed.

[1]Amer. Jour. Sci., vol. 27, 1835, pp. 168-171.
[2]Amer. Jour. Sci., vol. 28, 1835, pp. 104-111.
[3]Proc., Nat'l Inst. Promotion of Science, vol. 1, pp. 171-194, 1842.

Small unstudied collections of Pleistocene invertebrate fossils have been obtained in the vicinity of New Bern, Craven County, in the vicinity of Belhaven, Beaufort County, and in the vicinity of Swanquarter, Hyde County.

In 1896 Lewis Woolman[1] listed fossil mollusks and diatoms dredged from the Dismal Swamp Canal in Virginia and North Carolina, and concluded that the beds in which they were found are not older than the latest Pliocene and may belong to the Pleistocene. In 1902 N. H. Darton[2] referred these deposits to the Pliocene. Recent investigations in the region have led to the conclusion that the beds should be referred to the Pleistocene.

RECENT.

The recent deposits of the North Carolina Coastal Plain include the following: The fluviatile sands, clays, and gravels constituting the present flood plains of the streams; the alluvial sands and clays in process of deposition in lakes and ponds; the swamp deposits consisting of sands, muds, peats, etc., now being formed both in the upland swamps and in those bordering lakes, rivers, estuaries, and sounds; the terrace deposits now being formed beneath the surface of the water about the borders of estuaries and sounds and along the coast; and, lastly, such subaërial deposits as are being formed on the surface, including talus materials, alluvial fans at the base of valley slopes, and wind-blown sands.

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[1]Acad. Nat. Sci., Phila., Proc., 1898, pp. 414-424.
[2]Geologic Atlas U. S., folio No. 80, U. S. Geol. Survey, 1902.

CHAPTER III.

THE GEOLOGICAL HISTORY OF THE COASTAL PLAIN OF NORTH CAROLINA.

BY WM. BULLOCK CLARK, BENJAMIN L. MILLER, AND L. W. STEPHENSON.

The geological history of the North Carolina Coastal Plain embraces, as far as we have knowledge, that portion only of geological time covered by the series of unconsolidated sediments represented in the subaërial and submarine divisions of that district and already described in preceding pages. Whether older deposits of early Mesozoic or late Paleozoic age were ever deposited on the floor of crystalline rocks throughout any part of the present Coastal Plain district may never be known. The deep wells at various points near the coastal border have never revealed such strata, and it may be that this broad belt stood above sea level throughout these periods of geological history.

We know that the rocks of the Piedmont Plateau on which the deposits of the Coastal Plain rest had been extensively folded, faulted, and intruded by igneous rocks of varied types and the whole mass extensively metamorphosed before the close of the Paleozoic; also, that during Triassic time the Piedmont Plateau was invaded by extensive bodies of water which were probably partly or perhaps entirely cut off from connection with the open sea. These basins, produced by downward warping of the land surface or by faulting or by both, were then covered by extensive sheets of arenaceous and argillaceous sediments, with here and there interstratified carbonaceous beds and with intrusive and extrusive igneous rocks. Later these basins were elevated and drained, the strata faulted and the greater part of these materials then eroded by the streams that developed upon the surface, the débris being carried out and deposited in the main ocean. Between the time of the disappearance of these inland bodies of water and the beginning of Coastal Plain sedimentation another long period must have elapsed which probably included all of Jurassic time.

LOWER CRETACEOUS.

With the opening of Coastal Plain history at the close of the Jurassic or at the beginning of Cretaceous time there doubtless existed a great peneplain over the Piedmont Plateau. The floor on which the sediments of the Coastal Plain were laid down consisted of a great complex of crystalline rocks, some of undoubted sedimentary and some of

igneous origin, the former so altered as to no longer preserve the remains of organisms by which their age may be determined, while overlying these in places were Triassic sandstones, shales, conglomerates, and igneous rocks in the district to the west of the present Coastal Plain.

The base-leveled condition of this Piedmont region at the opening of the Cretaceous had permitted the deep decay of the rocks and removal by percolating waters of a large part of their more soluble constituents, as a result of which the remaining less easily soluble quartz, kaolin, and mica were rendered in a fit condition for rapid mechanical removal.

The large content of silica in the form of quartz grains, as a rule quite angular, which probably does not fall below 25 per cent even in the purest clays,[1] the usual large percentage of kaolin grains whose angularity in many instances shows them to have been deposited shortly after their removal from their source without subsequent reworking, and the common occurrence of muscovite mica as a rule fairly clear and giving a good biaxial figure, indicates that the source of the oldest Coastal Plain materials must have been, at least in large part, highly siliceous crystalline rocks.

When the causes inaugurating Coastal Plain deposition are considered it is evident that by a tilting of the land surface to the southeastward the Piedmont border was submerged and the region to the northwest was sufficiently elevated to set in motion the erosive forces of the streams, which immediately began to entrench themselves and to transport the products of the disintegration of the Piedmont crystalline rocks to the submerged region to the southeast. Whether this submergence was due to a warping which produced a long northeast-southwest trough, constituting a shallow inland sea or sound more or less completely shut off from the main open sea by land barriers to the east, or whether it was a shallow sea margin, is a question that cannot be satisfactorily answered. The lithologic nature of the deposits would seem to favor the former view. The absence of marine faunas and the presence chiefly of reptilian remains and fossil leaves would seem also to strengthen this interpretation. There is also evidence of a land barrier of some kind in the region about Wilmington in southeastern North Carolina as indicated by the absence there of beds representing the Patuxent formation, or in fact any sediments of the Lower Cretaceous, for a deep-well boring showed what are probably Upper Cretaceous beds resting directly upon basal granite at a depth of 1,109 feet.

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[1]See Bull. No. 13, N. C. Geol. Survey.

The main argument in favor of marginal origin is the great linear extent of the Lower Cretaceous terrane, for beds supposed to be of this age are known to occur from Maryland to Alabama.

Whatever its nature, the principal streams from the land to the northwest discharged their load of detrital matter into this body of water. Near the shore line the materials laid down were coarse and a high degree of cross-bedding was produced by the waves or in the deltas of the streams. Strong currents, however, swept out from the mouths of the principal streams to considerable distances from the land, and through the gradual checking of their velocities dropped their load of detrital matter, producing more or less homogeneous layers of sand of varying thickness in which cross-bedding was but subordinately developed. The fine argillaceous sediments which constitute the minor quantity of the mass were laid down in the quieter portions, forming broad clay lenses. The alternating layers of clay and sand were evidently produced by the occasional shifting of the main currents.

Just how long the sedimentation continued is not known, but it was finally brought to a close by an elevation of the region, producing a land surface. The forces of erosion became active and probably a large part of the sediments were removed and carried farther eastward into the main ocean, whose western shore may then have stood to the east of the present coast line.

The interval which elapsed between the deposition of these oldest sediments of the Coastal Plain and the inauguration of the next submergence of the region was very different, apparently, in the different portions of the Coastal Plain. To the northward through Virginia and Maryland transgression of the sea again took place before the close of the Lower Cretaceous, and a great formation known as the Patapsco formation, composed largely of clay and still containing chiefly plant remains, was deposited, remnants of which resting on the crystalline rocks may be found as far north as Pennsylvania, indicating a probably deeper submergence of the Piedmont Plateau in that direction than during the earlier epoch of the Lower Cretaceous. No evidence of these deposits has been found in North Carolina or farther southward, and it is probable that this southern region still stood above sea level.

UPPPER CRETACEOUS.

With the advent of the Upper Cretaceous the entire Coastal Plain district which had evidently been above sea level at the close of the Lower Cretaceous was now depressed throughout its entire extent from New York southward to the Gulf. The transgression of the sea started somewhat earlier in the north than in the south, as the presence of the

Raritan formation there bears evidence. The deposits everywhere, however, rest unconformably on the underlying Lower Cretaceous beds. With the progress of the epoch the Magothy and Matawan formations were laid down in the north, the Black Creek formation in the Carolinas and much of the Tuscaloosa, the Eutaw and evidently certain beds regarded as lower Ripley in the Gulf.

The materials were deposited during the earlier portion of the epoch under conditions very similar to those which had prevailed during the Lower Cretaceous. Shallow inland basins or sounds removed from the open sea bordered the coast. Throughout portions of the district coarse sediments were transported and deposited, although on the whole, and especially during the later portions of this epoch, the materials were finer and gave less evidence of shallow-water deposition. The submergence at this time probably did not extend as far inland as during the Lower Cretaceous or, if it did, the resulting deposits were afterwards removed. The land was probably not as high as it had been earlier, the streams were less swift and evidently bore large amounts of vegetable matter to the sea, as the trunks, twigs, leaves, and comminuted particles of land plants clearly show. With the upland species of plant life were also commingled the shore forms of the time, as has been already pointed out in an earlier chapter.

As the period advanced, important physical changes took place, resulting in deposits which in their nature were prophetic of the coming conditions favorable to the production of purely marine sediments. In the upper Black Creek beds glauconite is present in the sand laminæ and lenses and in places true greensand beds with a marine fauna are present, interstratified with the more typical laminated Black Creek beds, still containing a land flora. If the assumption of a land barrier be correct, the most simple explanation for these changes would seem to be that the barrier began to go down, perhaps with oscillations, so that for a while marine and land-locked conditions alternated, until, finally becoming entirely submerged, widespread marine conditions prevailed.

The conditions during this epoch differed somewhat in other portions of the Coastal Plain both to the north and south of North Carolina. To the north in New Jersey the marine conditions began earlier in Upper Cretaceous time, a few marine forms having already been found in the Raritan. With the coming of Magothy deposition, however, alternating marine beds become frequent, while in the Matawan only marine sediments have been found. Farther to the southward in South Jersey, Delaware, and Maryland the Raritan and the Magothy afford no marine fossils, the latter first appearing in the Matawan. The similarity of the Magothy and Matawan faunas in the northern region with those of

the Black Creek in North Carolina has been already pointed out. It is evident, therefore, that open-sea conditions prevailed much more widely in the far north and gradually became less pronounced southward. It is possible that the same conditions in the reverse order occurred to the southward of North Carolina toward the Gulf, where the intercalated marine sediments of the Eutaw succeed the Tuscaloosa. The close of this epoch saw the establishment of marine conditions throughout the Atlantic and Gulf borders. The barriers, whatever they were, had largely disappeared and the open sea probably covered the greater part of the Coastal Plain.

The remainder of the Upper Cretaceous period is everywhere characterized by marine sedimentation in which greensand marls predominate. Micaceous sands and clays also occur interstratified with the greensands, while shells of various marine organisms are at times present in such large quantities as to form beds rich in calcareous matter. The deposits are distinctly infralittoral in character, while the widespread presence of greensand shows that the area of deposition received its sediments slowly from the adjacent land. To-day greensand is found at some distance from the coast, where land-derived materials are deposited in small amounts. The conditions necessary for the production of greensand may have existed in Upper Cretaceous time nearer the coast if the adjacent land was low and the streams transported little sediment into the sea, as seems probable.

This epoch of Upper Cretaceous time represented along the South Atlantic coast by the Peedee beds of North and South Carolina, and by the greater portion of the Ripley formation in the Gulf border, saw the deposition of the Monmouth and Rancocas formations in Maryland, Delaware, and New Jersey, while in the latter State still more recent Cretaceous deposits appear in the Manasquan, which evidently represent the closing epoch of Upper Cretaceous time. To the southward elevation of the Coastal Plain began earlier as depression had started later, so that we have a much longer record of Cretaceous sedimentation in Maryland, Delaware, and New Jersey than elsewhere along the Atlantic border.

EOCENE.

The opening of Eocene time in the northern portions of the Coastal Plain found little change, as the oldest Eocene deposits of New Jersey (Shark River formation) apparently overlie the latest Cretaceous beds (Manasquan formation) conformably and are similar to them in being highly glauconitic. Depression extended gradually southward as Eocene time advanced, for in Maryland we have glauconitic strata of a later epoch of the Eocene, known as the Aquia and Nanjemoy formations,

lying unconformably upon the Cretaceous deposits. From Alabama to Texas deposition likewise went on during these earlier epochs of the Eocene, for deposits of that time are found overlying the Cretaceous strata throughout the Gulf region. In North Carolina, however, there is no indication of sedimentation during this time, although the deep cover of Miocene deposits over the northern part of North Carolina and the southern part of Virginia make it difficult to determine the southern extension of the northern Eocene. It has never been recognized at the surface or in well borings, however, within the limits of North Carolina. If such deposition occurred the deposits were subsequently removed throughout the subaërial portion of the Coastal Plain. The depression, however, of the late Eocene involved the region to the south of the Hatteras axis. This submergence evidently came from the southward, for the region to the north of Cape Hatteras shows no trace of strata of this epoch, while southward to the Gulf late Eocene deposits are widely found. The submergence throughout the southern part of North Carolina was extensive, the sea transgressing the former land surface as far inland as Wake and Harnett counties and as far northward as the valley of the Neuse River. The deposits of this epoch, represented by the Trent formation, are not found continuously over this area, although it is probable that the sea extended over the entire southern part of the State and perhaps had a much wider distribution than is indicated now by the remaining deposits, which have evidently suffered greatly from erosion.

The deposits show that the sea of the time was a favorable abode for marine life. Extensive deposits of molluscan and bryozoan shells are found wherever the formation has been observed. The water was probably shallow, as is indicated by the occasional coarse pebbles that are found within the deposits, materials that were evidently derived from the underlying Cretaceous or from the crystalline rocks. During this submergence the ocean transgressed the Cretaceous sediments and in the western part of the region covered the crystalline rocks which had perhaps remained above the water during much of the Paleozoic and all of the Mesozoic eras.

During the Trent submergence the adjoining region was evidently low and the streams that entered the ocean from the land brought very little terrigenous material, deposition consisting largely of calcareous mud in which vast quantities of molluscan shells were imbedded.

After the deposition of the Trent formation there was an uplift of the region and erosion succeeded sedimentation. How long this period of erosion persisted we cannot tell, but it was long enough for the complete removal of the Trent deposits over wide areas.

The Castle Hayne formation that follows rests unconformably upon the Trent formation as well as upon the Cretaceous deposits. It was probably formed during a gradual submergence which permitted the ocean water to again encroach upon the land, and the advancing waves, acting upon the loose sediments of previous periods, were able to accomplish considerable destruction. At the base of the Castle Hayne formation many Cretaceous fossils are found that were evidently torn from their original position and redeposited by the waves of the Castle Hayne epoch. Conditions similar to those that prevailed during the Trent epoch continued and deposits of calcareous mud containing many bryozoan and molluscan shells were formed. There is an almost complete absence of any land-derived materials. During this period sharks must have lived in great numbers, as is shown by the large quantities of sharks' teeth found in the deposits. Echinoids were likewise very abundant, while one species of brachiopod, *Terebratula wilmingtonensis,* is found represented by innumerable specimens.

So far as we can determine by the present distribution of the Castle Hayne formation, this later Eocene submergence did not extend over a wide area. The deposits are found in the extreme southeastern counties of the State, although it is not improbable that the sedimentation extended over a larger area and that the deposits have since been removed by erosion.

The Castle Hayne period was terminated by an elevation of the region that again caused erosion to succeed sedimentation. This next erosion interval was probably of long duration, for during this time in South Carolina, Georgia and the Gulf States extensive deposits of Oligocene strata were formed. In North Carolina the Oligocene seems to be wanting, although, perhaps, the Castle Hayne formation may eventually be referred to that period. The northern Coastal Plain likewise was evidently a land area, since Oligocene deposits have never been recognized in this region.

MIOCENE.

The advent of the Miocene period witnessed a depression of the Coastal Plain area along the Atlantic border. During the earlier epochs this was confined to the regions to the south and to the north of North Carolina. In Florida it was most pronounced, but it also affected the northern Coastal Plain district in New Jersey, Delaware, Maryland and northern Virginia. This northern Miocene depression represented by the Calvert and Choptank formations in the Chesapeake Bay region gradually extended southward until during the time that the St. Marys formation was being laid down in Maryland and Virginia the northern part of North Carolina also became involved and an extensive cover of

these deposits is found reaching quite to the border of the Piedmont Plateau throughout the region to the north of the Hatteras axis, extending as far south as the Neuse River and burying from view the older formations of the Coastal Plain. The transgression was evidently gradual, for the St. Marys deposits are found in Virginia and Maryland conformable to the earlier strata, and it is possible that these older beds exist beneath the St. Marys formation in North Carolina to the east of the area of outcrop.

Following the St. Marys epoch, deposition continued to the north of the Hatteras axis and was also inaugurated to the south of the same. A slight unconformity is found between the St. Marys and the later deposits known as the Yorktown formation, although the erosion interval, if such existed, was of short duration. To the south of the Hatteras axis the deposits of this epoch, known as the Duplin formation, rest everywhere unconformably on pre-Miocene deposits. Deposition was evidently widespread, although the deposits were extensively eroded prior to the Pleistocene.

The St. Marys deposits are mainly bluish-green argillaceous sands that are crowded with molluscan shells in places and in the marginal deposits contain many large pebbles derived from the underlying Cretaceous rocks and which were doubtless broken from them by the force of the advancing waves. During the St. Marys submergence the adjoining region must have been relatively low, for the streams from the land seem to have had little carrying power, since the sediments were mainly composed of small particles such as are carried by streams of moderate velocity.

The Yorktown and Duplin formations consist largely of fragmental molluscan shells in a matrix of medium fine quartz sand, although entire shells are numerous in many places. In some localities the fragmental character of the shells is especially noticeable and the beds resemble closely the shell deposits now accumulating in the vicinity of the beach in some of the coral islands of the West Indies. The waves were evidently responsible for the breaking of the shells which were deposited either on the shore or in shallow water in the vicinity of the land. The moderate thickness of the Yorktown and Duplin deposits would indicate a brief period of sedimentation. The submergence was terminated by an uplift which again brought the entire State above the level of the water. The uplift seems to have been sufficient to permit erosion to become active, the streams from the land soon removing in southern North Carolina the Duplin deposits over wide areas and leaving only those that were far from the streams or were protected by their position in depressions in the former land surface.

PLIOCENE.

The opening of the Pliocene period found the greater portion of the Coastal Plain above sea level. The region to the north of the Hatteras axis throughout the northern Coastal Plain was evidently not depressed during this time. No marine deposits have been with certainty recognized in this region. The southeastern part of North Carolina was, however, submerged in conjunction with extensive areas to the southward. The transgression of the sea covered a considerable region in North Carolina, although far less extensive than in the preceding Miocene period. The deposits constituting the Waccamaw formation are to-day found in isolated areas, but may have been and probably were continuous when laid down. The sediments derived both from the adjacent land and the underlying formations gave rise to strata consisting of sand and clay, inclosed in which are numerous fossil shells, so numerous in certain places that layers composed almost exclusively of them are found. The strata occurring at Neill's Eddy Landing illustrate this character of deposition.

Before the close of the Pliocene the land had probably been extensively denuded and the resulting materials carried far to the eastward. With the slackening of the currents of the Piedmont streams and the reduction of their transporting power the crystalline rocks gradually decayed and a deep cover of disintegrated rock blanketed the eastern Piedmont belt. Toward the close of the Pliocene period or possibly not until the opening of the Pleistocene there was a tilting of the land mass eastward and southward, resulting in the submergence of the Coastal Plain to the eastern border of the Piedmont Plateau, with a corresponding elevation, although perhaps not as great, to the westward. This change in the attitude of the Atlantic border region was accompanied with a submergence of the lowlands and valleys far within the confines of the Piedmont, as remnants of gravel deposits of this epoch are found at different points along the Atlantic border overlying the crystalline rocks more than 50 miles to the west of the Coastal Plain. The tilting of the region elevated the headwaters of the streams and brought about a revival of erosion and transportation, the detritus from the decayed rocks being strewn over the sea floor for the most part adjacent to the coast, where wave action, together with undertow, aided in forming the terrace mantle which enwrapped the eastern Piedmont belt, following its inequalities and extending in places far up the stream channels. This revival of the streams, accompanied by rapid sedimentation, resulted in the accumulation of only partially sorted deposits, coarse and fine materials being intermingled, with frequent evidences of cross-bedding.

The depression of the Piedmont border during this epoch was at least 500 feet, since that difference in elevation is found between the earlier and later Pliocene deposits. To the northward the elevation may have been much greater, since marine Pliocene deposits have not there been recognized within the subaërial division of the Coastal Plain. To the formation produced during this epoch the name of Lafayette has been given throughout the Gulf, where the name was first used, as well as along the Atlantic border where similar deposits have been found as far north as the highland bordering the valley of the Delaware in eastern Pennsylvania. No fossils of any significance have thus far been found in the deposits, so that the age of the strata must remain in doubt, although most geologists have regarded the Lafayette formation of Pliocene age, probably representing its closing epoch.

After the close of Lafayette deposition the land was again raised above sea level and subjected to extensive erosion. The streams of the eastern Piedmont have been shown already to have superimposed courses, and these are doubtless due to the cover of Lafayette deposits over much of this area. The relatively long period of erosion which followed compared with later time caused the opening up of the channels across the Coastal Plain in much the same position and form as they exist to-day, although they did not receive their full strength or final touches until the close of the Pleistocene.

Many writers have referred to the anomalous courses pursued by some of the larger streams of the district. Shattuck in reviewing this subject in connection with a study of the Coastal Plain drainage of Maryland, says:

"The anomalous course pursued by the Susquehanna after leaving the Piedmont, in turning south along the western margin of the Coastal Plain instead of continuing a direct course to the ocean, has arrested the attention of many geologists who have worked in this region. McGee thought this curious feature was to be explained by deformation along the 'fall line'; but Darton has suggested a more plausible cause. He believed that a submarine bar was built by the Lafayette approximately in the position now occupied by the Eastern Shore, and that a depression existed between this bar and the mainland. When the post-Lafayette uplift took place, this depression was changed to a slough, and down this trough the Susquehanna found its way. A similar state of affairs now exists off the coast of the Carolinas, where a great barrier beach cuts off the rivers from direct contact with the ocean. If this coast were to be lifted, Roanoke River would be deflected southward along the coast and follow the depression of Albemarle and Croatan sounds until a convenient opening could be found through the obstruction to the ocean beyond. It is probable that the channel of Chesapeake Bay was not so pronounced during the post-Lafayette uplift as later, when the subsequent formations had an opportunity to widen and lengthen this barrier first outlined by the Lafayette sea."

Some of the larger river channels of this period can be traced across the submarine division of the Coastal Plain toward the continental shelf. Whether these submerged drainage lines were wholly formed at the close of Lafayette time may be questioned. It is quite possible that the larger depressions may have already been outlined during earlier Tertiary epochs. This period of denudation was accompanied by extensive removal of Lafayette sediments. To the east of the thicker terrace accumulations they were apparently removed entirely, since no remnants of the Lafayette formation have been with certainty recognized beneath the Pleistocene cover except in proximity to the coastal margin of the Sunderland formation.

PLEISTOCENE.

With the advent of the Pleistocene period the land was again depressed, although not as deeply as during the Lafayette epoch. The ancient valleys were submerged and the sea gradually transgressed the interstream areas, removing and reassorting as a result of marine planation such remnants of the Lafayette as may have been left throughout this district. Depression at this time carried the sea from 200 to 300 feet above the present ocean level and a fringing terrace was formed against the Lafayette and older deposits. It can be traced to-day up the post-Lafayette valleys where it finally merges into the fluviatile deposits of the upper courses of the streams. It enwraps the unsubmerged portions of the pre-Lafayette Coastal Plain as well as the marginal portions of the Piedmont, just as the Lafayette terrace had enwrapped the still higher elevations during the preceding epoch.

The materials forming the earlier and highest terrace, known as the Sunderland throughout the middle and northern Coastal Plain, were evidently derived in part from reworked deposits of the Coastal Plain, and were also in part brought down by the Piedmont streams. Deposition was rapid, since the deposits attained only a moderate thickness and are generally poorly sorted, cross-bedding being everywhere present.

To the north of the Hatteras axis the sea evidently stood throughout this epoch at essentially the same elevation, but in southern North Carolina to the south of the Hatteras axis a subordinate change in elevation took place before the close of the epoch, producing two terraces which have been already described as the Coharie and the Sunderland. It seems probable that these conditions will be found extending still farther to the southward when that region has been more fully studied.

With the close of the Sunderland epoch elevation doubtless again took place throughout the Coastal Plain. Whether this elevation carried the submarine division of the Coastal Plain above the level of the

sea or not cannot be with certainty determined. It is significant, however, that deposits of Sunderland age have never been observed beneath the cover of later Pleistocene deposits throughout the eastern portion of the Coastal Plain district. Furthermore, there are numerous instances where valleys of Sunderland time have been buried by the materials of the next lower or Wicomico terrace. Every gradation is found from uneroded valleys to those in which the later materials have been swept out and the older valley lines widened and extended at the headwaters by renewed erosion. Again, many instances are found where the Wicomico sea, during the formation of the Wicomico terrace, reduced the headlands formed of Sunderland and earlier deposits. This reduction in the more diversified outline may well have been produced by the advance of a sea over the region, although neither this nor the preceding effects would necessarily demand extensive submergence.

The Wicomico terrace encircles the Sunderland terrace wherever observed at an elevation of about 100 feet along its landward margin and represents the position at which the sea stood during the Wicomico epoch. Its level-topped character is more pronounced than that of the preceding Sunderland terrace, since it has been less affected by denudation. The materials, together with their internal structure, suggest the same conditions of formation as those of the preceding epochs. This terrace or its equivalents have been traced from the northern Coastal Plain across Maryland and Virginia and thence across North Carolina, with the changes noted, to the South Carolina border.

Similar conditions evidently closed the Wicomico and ushered in the building of the Chowan-Pamlico (Talbot) terraces. At some points the remnants of Wicomico materials have been found beneath those of Talbot age, and it seems clear that the post-Wicomico elevation was not of sufficient extent for the removal of the Wicomico sediments over the entire eastern margin of the Coastal Plain. The same type of buried valleys and the same reduction in the configuration of the shore line marked the inner margin of the Talbot terrace as has been already described in the case of the earlier terraces. The materials are similar in character and structure to those which precede, and there is every reason to believe that they were formed under similar conditions. The Talbot terrace and its equivalent, the Chowan and Pamlico terraces, are again less dissected than the Wicomico. Imbedded in their materials are marine, estuarine, and fresh-water fossils dependent upon the position of the terraces with reference to the marine, brackish, and fresh waters of the period. Marine fossils have been found at numerous

points far up the valleys of the estuaries which show that the submergence of Talbot (Chowan and Pamlico) time carried the sea far into the interior of the land.

The height near the landward margin of the Talbot terrace throughout the northern Coastal Plain and of the Chowan terrace in Virginia and North Carolina shows that the sea stood at an elevation of 40 to 50 feet above its present level. During the building of the Pamlico terrace, on the other hand, it stood scarcely more than 20 feet. The great extent of the Pamlico terrace shows that a wide area in eastern North Carolina was still below sea level during that epoch.

To-day a similar terrace known as the Recent terrace enwraps the sea front and estuaries in exactly the same manner as the terraces of Talbot, Wicomico, Sunderland, and Lafayette time encircled the lands of those epochs. The materials and structure of the deposits are essentially identical with those of earlier date and there is every reason to believe that they find their explanation in the processes at work to-day in the building of this great recent formation.

CHAPTER IV.

THE CORRELATION OF THE COASTAL PLAIN FORMATIONS OF NORTH CAROLINA.

BY WM. BULLOCK CLARK.

The correlation of the geological formations of the North Carolina Coastal Plain is based on both physical and paleontological criteria. Among the physical elements that enter into such correlation are continuity of the strata, similarity of lithologic characters, similarity of sequence, and similarity of topographic form, while the paleontological factors, which are by far the most important generally for final discrimination, are based on identity of the species and the faunal and floral grouping.

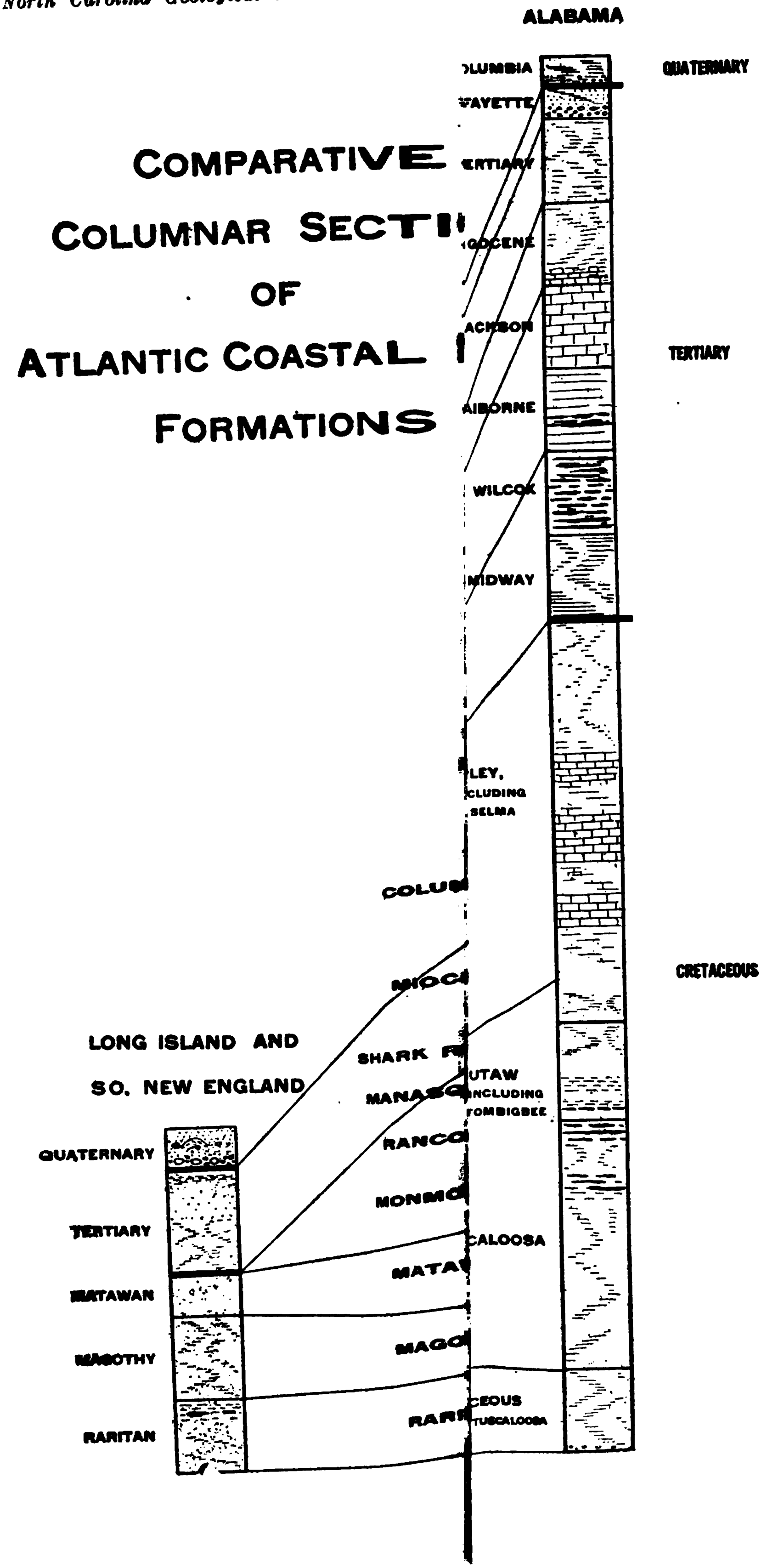
The physical criteria are alone available in the case of the Patuxent, Lafayette, Coharie, Sunderland, Wicomico, Chowan, and Pamlico formations, since fossils are either lacking or, when present, as in the case of some of the Pleistocene formations, are not sufficiently distinctive to be of any aid in establishing the equivalency of the deposits. The paleontological criteria are available in the case of the Black Creek, Peedee, Trent, Castle Hayne, St. Marys, Yorktown, Duplin, and Waccamaw formations, and with the physical criteria make it possible to approach the problem with a larger amount of evidence than in the case of the first group. It is fortunate, however, that in the case of the earliest and among the youngest formations the available physical criteria are such as to render their correlation quite as satisfactory as in the case of some of those of the second group.

Dr. L. W. Stephenson and Mr. E. W. Berry, under the direction of Dr. T. Wayland Vaughan, have greatly enlarged our knowledge of the stratigraphy and paleontology of the South Atlantic and Gulf States, and the results of their work have been available for the comparisons with the southern districts south of North Carolina.

The formations will be considered chronologically in the order of their occurrence.

PATUXENT FORMATION.

The Patuxent formation, in the absence of recognizable fossils, can only be correlated with the deposits of other areas on physical grounds. In stratigraphic position and lithologic character it is similar to the Patuxent deposits of Virginia and Maryland. The continuity of the strata is interrupted over a considerable area in southern Virginia, due


COMPARATIVE
COLUMNAR SECTI
OF
ATLANTIC COASTAL
FORMATIONS
ALABAMA
QUATERNARY
TERTIARY
CRETACEOUS
OLUMBIA
FAYETTE
ERTIARY
OCENE
ACKSON
AIBORNE
WILCOX
MIDWAY
LEY,
CLUDING
SELMA
UTAW
INCLUDING
TOMBIGBEE
CALOOSA
CEOUS
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RARI
LONG ISLAND AND
SO. NEW ENGLAND
QUATERNARY
TERTIARY
MATAWAN
MAGOTHY
RARITAN

to the transgression of later deposits, but similar interruptions occur at other points in Virginia and in Maryland where the sparse flora has permitted correlation on paleontological grounds. To the southward of North Carolina, on the other hand, similar deposits have been traced with only a few interruptions through South Carolina and Georgia into eastern Alabama, where fragmentary plant remains have been found which suggest a somewhat younger age for the deposits in this region than in the north.

These deposits in the far south were long erroneously associated with the Tuscaloosa formation farther westward in Alabama and Mississippi, from which, however, they are entirely distinct both in stratigraphic position and lithologic character, while they are separable everywhere by marked unconformities from the overlying Upper Cretaceous deposits. They are, according to the evidence at present available, physically continuous with the Patuxent beds farther north, whether or not the same formational name is employed throughout the entire district. Notwithstanding physical evidence in favor of a single formational unit being found at the base of the Coastal Plain series all the way from Maryland to Alabama, it must be admitted that a transgressing sea throughout so extended a coast line may well involve considerable time for its accomplishment, and if the transgression progressed from the north toward the south, as seems probable, the deposits in Alabama would necessarily be somewhat younger than those farther north.

The detailed comparison of the Patuxent deposits of North Carolina with those of adjacent regions indicate the stratigraphic and lithologic similarity of the strata over a wide area. The beds everywhere are characteristically arkosic and predominately arenaceous, with layers or lenses of clay. There is often a tendency to compactness and slight induration, while the colors are much the same everywhere. There is universal cross-bedding and bands of small pebbles here and there, indicating similar conditions of deposition in disturbed waters. In these respects the deposits are quite different from the overlying Arundel and Patapsco beds of Lower Cretaceous age, while it is quite clear that the deposits do not represent any portion of Upper Cretaceous sedimentation.

The flora of the Patuxent formation in Virginia and Maryland indicates that the deposits are of Neocomian age, and they have been thus correlated by Berry, who has made an extensive study of American Lower Cretaceous floras.

TABLE SHOWING CORRELATION OF LOWER CRETACEOUS FORMATIONS.

Approximate European Equivalents.	Pennsylvania and Delaware.	Maryland.	Virginia.	North Carolina.	Georgia and Eastern Alabama.
Albian	Patapsco	Patapsco	Patapsco		(?)
Aptian Barremian		Arundel			Lower Cretaceous. (Earlier referred to "Tuscaloosa.")
Neocomian		Patuxent	Patuxent	Patuxent	(?)

BLACK CREEK FORMATION.

The Black Creek formation presents much that is of correlative value, not only in its lithology and stratigraphy, but also in its contained fossils. When we apply the physical criteria to the correlation of the Black Creek beds we find that the deposits present many points of similarity with the Magothy-Matawan deposits of the northern area, with the Black Creek beds of South Carolina, and also with the Tuscaloosa and the Eutaw in the eastern Gulf. Everywhere along the Atlantic coast an unconformity separates these beds from those below, and this is also the case in eastern Alabama. Throughout the Atlantic coastal border these deposits, which are sands and clays, often cross-bedded, also afford interstratified marine beds containing more or less glauconite, and these gradually pass over into typically marine strata, which are widely glauconitic. No unconformity exists in the series as far as known. The beginning of sedimentation essentially glauconitic and permanently marine as shown by its contained fauna, while it may not have been inaugurated at exactly the same horizon at every point, already appears before the close of the Black Creek and synchronous deposits. Some modification in the character of sedimentation appears, to be sure, in different portions of the area, but the upper beds present many points of similarity throughout the entire region.

When we come to consider the evidence of the fossils, we find an extensive fauna and flora, each with a large representation of forms known in other areas. The fauna of the Black Creek formation has been collected at 24 different localities in the upper part of the formation, the fossils being found for the most part in glauconitic beds that are interstratified with the leaf-bearing zones.* Although there is more or less diversity in the forms at the several localities, certain species are common to the great majority of them. Although 92 species of invertebrates have been determined, of which 19 range on into the Peedee formation, the remainder, as far as known, not passing beyond the confines of the Black Creek formation. A comparison of this fauna with

*The ranges of the species in the Black Creek and Peedee formations have been revised by Dr. Stephenson in the light of his more recent studies. (See table opposite p. 147.)

that of New Jersey shows a remarkable similarity with the Magothy-Matawan horizons. Out of the 43 species found in the Black Creek that have been recognized in the New Jersey Cretaceous, 23 are confined to the Magothy-Matawan, while 20 pass upward into the Monmouth. Of the 23 restricted forms in New Jersey 19 are similarly restricted in North Carolina. On the other hand, of the 20 species which range upward into the Monmouth in New Jersey 7 also range upward into the Peedee in North Carolina, and this similarity may be still more marked when more complete collections have been made from the Peedee beds. The 19 forms common to and confined to the Black Creek formation in North Carolina and to the Magothy and Matawan formations in New Jersey are:

Nucula percrassa Conrad, *Nemodon brevifrons* Conrad, *Trigonoarca triquetra* Conrad, *Trigonoarca cliffwoodensis* Weller, *Glycymeris congesta* (Conrad), *Pterea petrosa* Conrad, *Exogyra ponderosa* Roemer, *Ostrea cretacea* Morton, *Cymella bella* Conrad, *Eriphyla conradi* (Whitfield), *Cardium eufaulense* Conrad, *Isocardia cliffwoodensis* Weller, *Schizodesma appressa* Gabb, *Corbula carolinensis* Conrad, *C. bisulcata* Conrad, *Cadulus obnutus* (Conrad), *Gyrodes crenata* (Conrad), *Turritella quadrilira* Johns, *Pugnellus densatus* Conrad, *Placenticeras placenta* (DeKay).

It is of interest that among these, *Trigonoarca triquetra* Conrad, *Trigonoarca cliffwoodensis* Weller, and *Ostrea cretacea* Morton are confined to the Magothy alone, while *Exogyra ponderosa* Roemer, *Eriphyla conradi* (Whitfield), *Cardium eufaulense* Conrad, *Isocardia cliffwoodensis* Weller, *Cadulus obnutus* (Conrad), *Gyrodes crenata* Conrad, *Pugnellus densatus* Conrad, and *Placenticeras placenta* (DeKay), have only been found in the Matawan. The remaining forms have been found at both horizons.

Ostrea tecticosta Gabb, *Trigonia eufalensis* Gabb, and *Turritella trilira* Conrad, which have not been found above the Matawan, range into the Peedee in North Carolina. On the other hand, out of the 20 Black Creek forms which are found in both the Magothy-Matawan and the Monmouth, *Cucullaea antrosa* Morton, *Ostrea plumosa* Morton, *Gryphaea vesicularis* Whitfield, *Lima reticulata* Forbes, *Anomia argentaria* (Morton), and *Cardium spillmani* Conrad are also found in both the Black Creek and Peedee in North Carolina, while the remainder, which range upwards into the Monmouth, have not been hitherto observed in the Peedee of North Carolina. Of these, however, *Cyprimeria densata* (Conrad) and *Linearia metastriata* Conrad are especially characteristic of the Matawan formation in the northern Coastal Plain, although also found higher in the series.

The marked similarity of the Black Creek fauna with that found in the Magothy-Matawan series is thus clearly shown. Although the differentiation of this fauna into faunules as described by Weller for the New Jersey region cannot be made, it is significant that such forms as *Belemnitella americana* (Morton), *Ostrea larva* Lam.,[1] *Exogyra costata* Say, and *Pecten tenuitestus* Gabb introduced at the opening of the Monmouth in New Jersey are likewise not found below the Peedee in North Carolina. The reappearance of the earlier faunal facies as a distinct faunule after the introduction of the *Belemnitella* fauna, as shown in the Redbank beds in New Jersey, has not been recognized farther south, a fact that is perhaps to be explained on the ground that the physical conditions necessary for the reintroduction of these forms did not again occur south of New Jersey. It is apparent, therefore, from the faunal evidence submitted that the Black Creek formation of North Carolina is to be correlated with the Magothy-Matawan formations of the northern Coastal Plain.

When a comparison is instituted with the Gulf Cretaceous, it is more difficult to correlate the deposits, since the range of the species in the Gulf series has never been determined with care. There is little doubt but that the Black Creek-Peedee faunas combined are the equivalent of the Magothy-Matawan-Monmouth of the northern part of the Coastal Plain and that these find their counterpart in the Eutaw-Selma-Ripley of the eastern Gulf.

The eastern Gulf faunas are being studied at the present time by Dr. L. W. Stephenson. An extensive fauna has been found at certain localities in the Eutaw formation as well as in the Lower Ripley (or Selma), and many of the forms which are limited to the Black Creek beds in North Carolina and the Magothy-Matawan of the region farther north are found to be likewise limited to the Eutaw and lower Ripley (or lower Selma). The studies of Stephenson have shown, however, that, of the 19 species common to, and confined to the Black Creek formation of the Carolinas and the Magothy-Matawan of New Jersey, 9 range upward into the upper Ripley, or what he has termed the *Exogyra costata* zone, of the eastern Gulf region. These are as follows: *Nucula percrassa* Conrad, *Nemodon brevifrons* Conrad, *Pteria petrosa* (Conrad), *Cymella bella* Conrad, *Cardium eufaulense* Conrad, *Schizodesma appressa* Gabb, *Cadulus obnutus* (Conrad), *Gyrodes crenata* (Conrad), and *Pugnellus densatus* Conrad. These species appear, therefore, to have a higher range in the Gulf region than they are known to have in the Atlantic coast region.

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[1]*Ostrea falcata* Morton, found in the upper Matawan, has been referred by some writers to this species.

When a comparison of the fauna of the Black Creek formation is made with that of the European Cretaceous, we find that its general character is that of the Senonian, and the view has been commonly held by paleontologists that all of the marine beds of the Atlantic and eastern Gulf coasts represent that epoch of the Cretaceous, with the possible exception of certain later deposits in New Jersey which have been regarded by the writer and others as of Danian age. Some even include in the Senonian all of the Upper Cretaceous strata, both marine and nonmarine, from New Jersey to the Mississippi basin, since even the lowest known Upper Cretaceous deposits in this area (Raritan formation) contain a few marine invertebrates of probably identical species with those of higher horizons. Those who hold this view necessarily consider that the earlier Turonian and Cenomanian epochs are unrepresented, since every one agrees that the unconformably underlying deposits are of Lower Cretaceous age.

It is essential, however, before passing final judgment on the basis of marine invertebrates, to examine the evidence furnished by the fossil plants which occur in great variety in the lowest beds beneath those containing the marine invertebrates as well as in interbedded strata in the middle of the series.

Mr. E. W. Berry of the Johns Hopkins University, who has made a study of the flora of the formation, has prepared the following statement regarding the significance of the plant remains. He says:

"Fossil plants have been collected at 21 different localities within the Black Creek formation of North Carolina. These collections are of very unequal interest, ranging from those made up entirely of detached leaves of *Araucaria bladenensis* Berry to that at Court House Bluff, where 45 different species are represented. The great bulk of the localities show but little individual diversity in their fossils, the conditions of sedimentation during the formation of the deposits eliminating in most instances many of the more delicate types and in some cases even reducing them all to an unrecognizable condition. Among the most resistant and at the same time most common types are *Araucaria bladenensis* Berry and *Pistia Nordenskioldi* (Heer) Berry. Some other less common forms, such as *Andromeda novaecaesareae* Hollick, are almost equally capable of withstanding maceration. Evidently all of the plants were in the water a considerable time before fossilization, as the coriaceous leaves of *Araucaria bladenensis* Berry which successfully resisted destruction in the triturating currents which cross-bedded the sands have lost all trace of their internal structure. Furthermore, the less resistant forms at Court House Bluff which owed their preservation to somewhat more favorable physical conditions, likewise show evidence of having been in the water a long time through the almost universal absence of apex and base and the frayed condition of the margin of many of the leaves, as commonly seen in the very abundant *Myrica*

[illegible] The [illegible] at this locality [illegible] of [illegible] are [illegible] the [illegible] of [illegible] with the [illegible] and [illegible] at this locality may be [illegible] near the mouth of a [illegible] river [illegible] which [illegible] the [illegible] *Laurophyllum* [illegible] *Magnolia* [illegible] *Quercus* [illegible] and [illegible] with *Araucaria* [illegible] Berry [illegible] from the [illegible] the [illegible] above the [illegible] of [illegible]. About [illegible] have been described from [illegible] of the localities.

"This flora is [illegible] of the [illegible] of the formation at the lower Black River localities [illegible] Black Creek [illegible] and Horrell Landing. [illegible] Berry occurs [illegible] along the [illegible] of the Black Creek with the underlying Patuxent formation along [illegible] Creek and [illegible] Here Berry occurs at [illegible] Bluff on the upper Neuse River towards the landward margin of the formation. Likewise the plants from the most northerly outcrops along the Tar River show exactly the same forms as occur on the lower Black River [illegible] to the southward and 50 miles from the landward margin of the formation.

"The Black Creek flora is unquestionably of Upper Cretaceous age. It is more complex and modern in its composition than any known Lower Cretaceous flora, not a single dicotyledon being known from the English Gault while the representation of this group of plants in the corresponding Albian of continental Europe is very meager indeed; in the Black Creek, on the other hand, 70 per cent of the species belong to this class. Furthermore, the Black Creek altogether lacks the fern element which is so prominent in the Lower Cretaceous, and the gymnosperms are less varied than in even the basal formations of the Upper Cretaceous (Raritan, Atane).

"There are several Black Creek species that are deserving of special emphasis in any consideration of correlation. Among these *Araucaria bladenensis* Berry is the most important, being found often in great abundance, at 14 out of the 21 plant localities in the formation. It occurs also in the Black Creek beds of South Carolina, in the equivalent of the Eutaw along the Chattahoochee River in western Georgia, at the summit of the Tuscaloosa formation in Alabama, and also at the summit of the Magothy formation in Maryland. The nearest allies of this species are *Araucarites ovatus* Hollick of the Magothy formation and *Araucaria Toucasi* Sap. of the Turonian of France. Two other species of this genus occur in the Black Creek formation, but no representatives of this type have ever been found in deposits of Raritan age. *Ficus stephensoni* Berry, a new species of fig, is confined to the Black Creek and to the Middendorf beds of South Carolina. Its nearest relative is a species described by Lesquereux from the Dakota Group. *Leguminosites robiniafolia* Berry, another new species, is likewise confined to the Black Creek and Middendorf beds, as is also *Quercus pseudowestfalica* Berry. The writer has elsewhere emphasized the presence of oaks in any abundance as a feature indicating the post-Raritan age of the Magothy and allied formations. Two species of *Quercus* are described from the Black Creek, and the apparently synchronous

Middendorf beds across the border in South Carolina have a varied display of oaks, rivaling in this respect the Dakota Group of the west. Both *Sequoia heterophylla* Velen. and *Sequoia minor* Velen. of the Black Creek were first described from the Cenomanian of Bohemia, and the former also persists into the Senonian of that country. It is a characteristic and widespread species throughout the Magothy formation, making its first appearance in American strata in the uppermost Raritan at South Amboy, New Jersey. *Pistia Nordenskioldi* (Heer) Berry occurs, often in great abundance, at 8 of the plant localities in the Black Creek, its only other known occurrences being near the top of the Magothy formation in Maryland and in the Atane beds of Greenland, supposedly of Cenomanian age, but closely related, according to the observations of White and Schuchert, with the overlying Patoot beds (Senonian?). The only other fossil representatives of this genus are *Pistia Mazelii*, described by Saporta and Marion from the Senonian lignites of Fuveau, France, and *Pistia corrugata*, described by Lesquereux from the Montana formation of Wyoming, both very distinct from the Black Creek plant. Among the common plant remains in the Black Creek are certain characteristic fruits which have been described by the writer as *Cephalotaxospermum carolinianum*. They are a marked feature of these deposits, occurring at 5 of the localities. Outside the State they are found in the Black Creek shales of South Carolina and at the top of the Tuscaloosa in Alabama.

"Recently a single species of fossil plant, the only one known from this formation, was collected by Dr. H. P. Little in a carbonate of iron nodule in the Woodbury clays (Matawan) at Lorillard, New Jersey. It proves to be very close to the common Magothy and Dakota Group form *Ficus reticulata* (Lesq.) Knowlton,[1] which Hollick also recorded recently from the supposed Magothy formation of Marthas Vineyard and which he regards as also identical with *Myrtophyllum schubleri*, described by Heer from the Cenomanian of Moravia.[2] Furthermore, *Dammara cliffwoodensis* Hollick, a characteristic Magothy plant closely related to *Dammara borealis* Heer of the Raritan and Tuscaloosa, has been collected in the Matawan formation of Maryland. These occurrences clearly indicate, what has long been suspected, that the Magothy flora persisted well into Matawan time.

"Similar conditions are shown by a recent collection of fossil plants made by Dr. L. W. Stephenson near Buena Vista in western Georgia. In beds said to be above the Blufftown or Snow Hill horizon of the Lower Ripley the writer has identified *Araucaria bladenensis* Berry, *Andromeda novae-caesareae* Hollick, and *Manihotites* sp., 3 characteristic Black Creek forms out of a total flora of but 6 species, 1 other of which, *Eucalyptus angusta* Velen., occurs in the Middendorf beds of South Carolina, the evident equivalent of the Black Creek, and in the upper Raritan of New Jersey.

"Comparing this flora as a whole with that of related formations, it may be noted that 28 of the Black Creek plants occur in the Raritan formation. While this seems like a large percentage, it is to be remembered that only 13 of these were described originally from the Raritan, and that all but one or two of the remainder are species described from higher horizons, from the Dakota Group of the west, and from the Cenomanian and Senonian of Green-

[1]Berry, N. Y. Bot. Garden, vol. 3, 1903, p. 73, pl. lii, fig. 5; pl. liii, figs. 1, 4.
[2]Hollick, Mon. U. S. Geol. Survey, vol. 1, 1907, p. 96, pl. xxxvi, fig. 6.

land, Saxony, and Rhenish Prussia. The Black Creek altogether lacks the fern remains and the other elements of the Raritan formation of New Jersey which are to be considered as survivals from the flora of the Lower Cretaceous Patapsco formation. Twenty-seven of the Black Creek species occur in the Magothy formation of New Jersey and Maryland, the flora of the latter containing several as yet unpublished additions to this list. While this is a less number than is common to the Raritan, it embraces certain forms which, although making their first appearance in the upper Raritan at South Amboy, New Jersey, and Kreischerville, Staten Island, are especially characteristic of the Magothy formation. Among the characteristic forms common to the Black Creek and the Magothy may be mentioned *Araucaria bladenensis* Berry, *Andromeda novae-caesareae* Hollick, various species of *Eucalyptus*, *Magnolia Capellinii* Heer, *Moriconia americana* Berry, *Pistia Nordenskioldi* (Heer) Berry, *Pinus raritanensis* Berry, *Podozamites Knowltoni* Berry, *Salix flexuosa* Newb., and *Lesquereuxi* Berry, etc. A typical Magothy species described originally from the Senonian of Europe and not found in Raritan deposits is *Cunninghamites elegans* (Corda) Endl., which is very abundant in the lower Black River beds. Seventeen of the Black Creek species occur in the Dakota sandstone, 14 in the Atane beds of Greenland, 6 in the Patoot beds of Greenland, 8 in the Cenomanian of Moravia, 2 in the Cenomanian of Dalmatia, 8 in the Cenomanian of Bohemia, 3 in the Turonian of France, 1 in the Senonian of Bulgaria, and 2 in the Senonian of Westphalia and Prussia.

"The character of the Black Creek flora as a whole shows conclusively that it is younger than the Raritan flora and must be correlated with that of the Magothy formation of the northern Coastal Plain and with at least the major part of the upper Tuscaloosa and the lower Eutaw of Alabama with which it is practically connected by certain as yet poorly defined formations in South Carolina and Georgia. It is also to be correlated with the Dakota Group flora of the west.

"Regarding the broader question of detailed correlation with the European time scale, it is perhaps premature to speak at the present time. In a forthcoming report for the New Jersey Geological Survey the Cenomanian age of the Raritan formation is shown in detail.[1] The evidence of the fossil plants is such, however, that the Magothy, Black Creek and upper Tuscaloosa formations must be regarded as either late Cenomanian or possible Turonian age. The latter supposition is not capable of direct proof, since the Turonian flora of Europe is too meager to form any basis for comparison.[2] It rests on the assumption that the Dakota Group flora should, along with the overlying Benton fauna, be referred to this stage, since the latter has been generally regarded as earlier than the Senonian. The Magothy and Black Creek floras cannot be younger than that of the Dakota Group, which has always been considered as of Cenomanian age."

The evidence afforded, therefore, by the invertebrates and plants is apparently in conflict, since the former present a Senonian facies

[1]Berry, Jour. Geol., vol. 18, pp. 252-258, 1910.

[2]Through the kindness of Professor Laurent, the writer has received a list of the Turonian plants of Southern France contained in the Museum at Marseilles. Out of a total of 15 species provisionally recognized, 4 are identical with Black Creek or Magothy forms, while *Araucaria Toucasi* Sap. represents *Araucaria bladenensis* Berry.

throughout, according to certain authorities, while the latter are regarded by paleobotanists to show an unequivocally Cenomanian facies in the lower portion of the series, although they admit that the higher leaf-bearing horizons may be with propriety assigned to the Turonian. In this connection we find in the western Gulf that the Woodbine formation, which is the representative of the Dakota sandstone farther west and which contains, as already pointed out, a Black Creek-Magothy-Tuscaloosa flora, is succeeded by marine beds known as the Eagle Ford and Austin Chalk formations, which represent the Colorado Group farther west, and that these are again succeeded by deposits containing the Ripley fauna, the latter being regarded as the equivalent of the Montana group of the Rocky Mountain district. Since the Dakota has been generally regarded as containing a Cenomanian flora and the Montana a Senonian fauna and flora, the Colorado and its equivalents may perhaps be properly assigned to the Turonian. Since the Montana flora is regarded by paleobotanists as absolutely distinct from and much younger in its facies than the Dakota, it is difficult to see how, as some have supposed, the entire series of Upper Cretaceous sediments on the Atlantic and eastern Gulf coasts can be assigned to the Senonian, a view still further weakened by the fact that the Woodbine beds are probably stratigraphically continuous beneath the Mississippi embayment with the Tuscaloosa deposits farther east in which the same flora occurs. A much more exhaustive study of the stratigraphy of the Cretaceous deposits of the central and western Gulf regions is clearly demanded, however, before these questions can be finally settled.

It is apparent, therefore, unless the evidence of paleobotany is to be entirely ignored and the Senonian age of the invertebrates accepted without question—a conclusion which has not been proven for the entire series as yet—that we are still forced to consider the possibility of the Upper Cretaceous sediments of the Atlantic and eastern Gulf coasts representing horizons earlier than the Senonian. Since the Turonian has not been recognized by either a distinct fauna or flora in the series of conformable strata under consideration, it is quite possible that a Cenomanian flora once established continued its existence in America later than the close of the Cenomanian epoch in Europe. At the same time it is conceivable that the earlier elements of the invertebrate fauna are somewhat older than paleozoologists have recognized, and that a greater or less portion of the series under discussion must therefore be regarded as Turonian.[1] The evidence of the plants is

[1]Since the above was written, the studies of Stephenson, not yet published, show the close similarity of the Eutaw (Tombigbee) faunas with those of the Austin chalk of the western Gulf, which in turn is correlated with a part of the Colorado group of the western interior, thus establishing the pre-Montana age of the Eutaw and Tuscaloosa formations.

certainly favorable to this interpretation, as the European Turonian flora is a very sparse one and presents some marked points of agreement with the flora under consideration.

In conclusion, it may be well to direct attention to the fact that the use of the minor European time divisions of the Cretaceous in this connection may well be questioned in any event, as it is clear from the conflicting evidence presented that it is impossible to assign sharply defined limits to them in the Atlantic and eastern Gulf regions.

PEEDEE FORMATION.

The criteria for the correlation of the Peedee formation have already been largely discussed in connection with the Black Creek formation. The persistent glauconitic character of the materials, although containing interstratified beds of different character, some arenaceous and some argillaceous, suggest similar conditions of deposition over wide areas. Almost identical materials are found in the Monmouth formation farther north, the Peedee marls in South Carolina, and in the upper portion of the Ripley-Selma series of the Gulf. Throughout the Atlantic and eastern Gulf areas these deposits overlie the older strata conformably. As far, therefore, as the physical criteria are concerned, the Monmouth, Peedee, and upper Ripley-Selma seem to be synchronous deposits.

The paleontological criteria are confined to animal remains, since no plants have been recognized in the deposits, and it is doubtful if beds so strictly marine are liable to afford any. The animal remains are not as numerous as in the Black Creek, only 35 invertebrate species having been recognized thus far. Of these the following 14 are confined to the Peedee formation: *Ostrea subspatulata* Forbes, *Ostrea larva* Lamarck, *Exogyra costata* Say, *Exogyra costata* var. nov., *Pecten tenuitestus* Gabb, *Lima acutilineata* (Conrad), *Paranomia scabra* (Morton), *Crenella serica* Conrad, *Pholadomya* sp. nov. (same as sp. nov. from Pataula Creek, Ga.), *Liopistha protexta* Conrad, *Panopea decisa* Conrad, *Turritella vertebroides* Morton, *Sphenodiscus lenticularis* (Owen), and *Belemnitella americana* Morton. Of the species named the following four are known to range downward into the equivalents of the Black Creek formation, either in the eastern Gulf region or in New Jersey: *Ostrea larva* Lamarck, *Paranomia scabra* (Morton), *Crenella serica* Conrad, and *Panopea decisa* Conrad. A number of other species, including *Cucullaea antrosa* Morton, *Ostrea plumosa* Morton, *Gryphaea vesicularis* Lam., *Lima reticulata* Forbes, *Anomia argentaria* (Morton), and

Cardium spillmani Conrad, are found at both horizons. Still others found both in the Peedee and Black Creek in North Carolina are confined to the Monmouth in the north, among them *Pecten simplicius* Conrad and *Lima pelagica* (Morton). The fauna as a whole is, however, clearly that of the Monmouth and upper Ripley.

The Peedee in North Carolina is not followed by younger Cretaceous deposits, as in New Jersey, where a decidedly younger fauna quite distinct from that in the lower beds is found. The Peedee formation is overlain only by Tertiary or post-Tertiary deposits, so that its upper limits are everywhere sharply defined on both physical and paleontological grounds.

As already stated, this fauna has been generally regarded as Senonian, while the overlying Cretaceous fauna in New Jersey has been regarded by the writer and others as probably Danian in age.

TABLE SHOWING CORRELATION OF UPPER CRETACEOUS FORMATIONS.

Approximate European Equivalents.	Delaware and Maryland.	Virginia.	North Carolina.	Alabama.
Danian	Rancocas			
Senonian	Monmouth		Peedee	Ripley, Selma. Eutaw.
Turonian	Matawan Magothy	In well borings	Black Creek	Tuscaloosa.
Cenomanian	Raritan			

TRENT FORMATION.

The Trent formation lies unconformably on the underlying Cretaceous deposits. The lithologic materials are very unlike those of the Eocene of adjacent States, consisting of a light-colored marl that is either loose or locally consolidated. The strata were evidently deposited after a long interval of erosion, but there is nothing in the position or character of the beds that renders it possible to correlate them with certainty with the Eocene of adjacent areas. In some particulars the beds, both in position and character, suggest the Santee marl of South Carolina, which has been regarded as belonging in the Claiborne group. It is quite possible that they may belong to that horizon.

The fossils of the Trent horizon are largely casts of marine forms, although in a few instances teeth and shells are preserved. The groups best represented are the mollusca, bryozoa, and echinodermata. A large oyster which has been identified as *Ostrea georgiana* Conrad, sev-

eral echinoids, among them *Scutella alta* Conrad and *Echinocyamus parvus* Emmons, the latter found in the Gosport sand of Alabama, suggest the upper Claiborne age of the strata. The numerous molluscan casts, which are for the most part simply molds of the interiors, make it very difficult to determine the species with accuracy. It is therefore impossible at present, with such material, to correlate the beds definitely, although the general character of the fauna points to their late Claiborne or early Jackson age.

CASTLE HAYNE FORMATION.

The Castle Hayne apparently overlies the Trent formation unconformably wherever the two come in contact. The relations of the Castle Hayne to the Trent formation are not clear, since their contact has not been observed in any outcrop, but is only known from well borings. It seems probable, however, that they are unconformable and that an erosion interval existed between them. The materials are quite different from those of the Trent formation, the most common constituent being a fossiliferous limestone of varied hardness and purity. A loose calcareous marl and glauconitic sands and clays are also found. A pebble bed more or less phosphatic is found at the base. The general stratigraphic relations, therefore, suggest a formation distinctly later than the Trent formation in age. No deposits of similar character are seen in adjacent States, so that the more detailed correlation of the beds must rest wholly on the organic remains.

The fossils of the Castle Hayne limestone are numerous. They consist, as in the Trent formation, largely of casts which render their specific determination difficult. Among the more perfectly preserved forms are several which are confined to the Wilmington area, and therefore of very little aid in the correlation of the deposits. Among the important forms are: *Terebratulina lachryma* Morton, *Conus gyratus* Conrad, *Crassatellites altus* Conrad, *Pecten scintillatus* Conrad, *Spondylus dumosus* Conrad, and a number of species which cannot be determined, but whose generic relations suggest the late Eocene age of the formation and its correlation with the beds at the top of the Jacksonian, and Vaughan believes that the Castle Hayne formation should be thus referred. The bryozoa, on the other hand, suggest the Vicksburgian age of the deposits, and Bassler, who has examined the forms with care, is inclined to think that they should be referred to that horizon, which would make them Oligocene in age. A more detailed study of the fauna is required to determine whether the formation is to be placed in the late Eocene or early Oligocene.

TABLE SHOWING CORRELATION OF EOCENE FORMATIONS.

	NEW JERSEY.	MARYLAND AND VIRGINIA.	NORTH CAROLINA.	ALABAMA.
			Castle Hayne	Jackson.
			Trent	Claiborne.
Eocene		Nanjemoy		Wilcox.
		Aquia		
	Shark River			Midway.

ST. MARYS FORMATION.

The St. Marys formation rests unconformably on underlying deposits. Its continuity with the St. Marys formation of Virginia and Maryland has been established. The beds have been studied throughout the entire area from Maryland to North Carolina. The materials, which consist predominantly of argillaceous sands, often of a dark bluish-green color with coarser beds interstratified, present the same characteristic features throughout the entire district. They have been examined in successive river basins, and there seems to be little doubt but that they are stratigraphically continuous throughout.

The more sandy phase of the Chesapeake Group, recognized under the name of the Choptank formation in Maryland, gradually dies out near the Virginia line, while the underlying Calvert formation with its basal diatomaceous beds gradually disappears between Petersburg and the North Carolina line, beyond which the St. Marys formation directly overlies the older deposits.

The fossils are very numerous and characteristic. Dr. Julia A. Gardner of the Johns Hopkins University, who has been engaged in an exhaustive study of the Virginia and North Carolina Miocene faunas, has prepared the following statement regarding their significance. She says:

"The Miocene in Maryland has on paleontologic as well as lithologic grounds a threefold division, the Calvert, Choptank, and St. Marys. The Calvert fauna is distinguished by the temperate element so prominent in it. Of the forms peculiar to the Calvert in Maryland and occurring outside of the State, 56% are found in the Miocene at Shiloh and Jericho, New Jersey. The Choptank fauna is merely the biologic expression of changing physical conditions and is, in general, a sandy-bottom facies of the Calvert. The St. Marys is differentiated by an influx of new forms and by the absence of those species peculiar to the cooler water of the Calvert and the sands of the Choptank. It is, however, rather unsatisfactory as a reference fauna. Although 43% of the St.

Marys species occur without the State, only 70% of these are confined to the Chesapeake group, and hence are available as horizon markers. The forms which have not, as yet, been reported from above or below the St. Marys are as follows:

Murex conradi Dall.
Urosalpinx rusticus Conrad.
Calliostoma humile Conrad.
Calliostoma reclusum Conrad.
Fissuridea alticosta Conrad.
Sportella pelex Dall.
Astarte symmetrica Conrad.
Arca virginiae Wagner.

"Of these eight forms *Astarte symmetrica*, though very rare in Maryland, has been the most valuable diagnostic species in the North Carolina work. The gastropods and the three species of *Arca* are rare south of the Virginia line, while *Sportella pelex* is a small form and very easily overlooked in any but the most detailed examination of a fauna.

"Collections from the St. Marys of North Carolina have been made at 76 localities, and though the determinative work is only partially completed, the preliminary lists give the dominant characteristics of the fauna. The general aspect is fairly constant throughout the region. The forms are for the most part well preserved, though at certain points along the Meherrin they are too soft and friable to be separated from the matrix. In the North Carolina St. Marys the most common pelecypods are *Mulinia congesta*, numerous species of Pecten, especially *jeffersonius* and its varieties; *Ostrea compressirostra* and *Ostrea sculpturata* in about equal numbers, *Crassatellites*, *Venus rileyi* and the massive variety *tridacnoides*, *Glycymeris subovata*, more rarely *Glycymeris americana*, *Dosinia acetabulum*, several species of *Phacoides* and *Yoldia laevis*. *Astarte symmetrica*, which has not as yet been found outside of the limits of the St. Marys, occurs throughout the area, though less profusely than *Astarte undulata*. The minute forms make up a much smaller percentage of the total fauna than in the later Tertiary. *Corbula inaequalis* is abundant, as is also *Leda acuta*. *Gemma* occurs, but not commonly. *Nucula* is rare at most of the localities, though at Hamilton Bluff it is the most conspicuous fossil. Of the gastropods, *Turritella variabilis* is, by far, the most abundant. In Maryland this form is confined to the St. Marys. Outside of the State it occurs at higher horizons, but usually with variations. The larger species of *Fulgur*, so common at Yorktown, are rather rare and usually fragmentary. *Polynices duplicatus*, *Crepidula aculeata*, and *Crepidula fornicata* are extremely abundant, while numerous species of *Calliostoma*, *Crucibulum*, *Fissuridea*, the *Nassidae* and the *Buccinidae*, together with *Ecphora quadricostata*, are found in relatively few numbers. The small gastropods, like the small pelecypods, are limited in species and in individuals. The scaphopods are best represented by *Dentalium attenuatum*, which is almost universal in its occurrence throughout the area.

This rapid reconnaissance may serve to bring out the general features of the St. Marys fauna in North Carolina. The characteristics which distinguish it from the Yorktown will be discussed under the latter formation. Two criteria serve to differentiate the North Carolina Chesapeake from the Maryland

Calvert. The first of these is the absence of the cooler water element so characteristic of the latter. In Maryland, the northern component comprises 56% of the Calvert forms available as diagnostic species outside of the State, the more abundant species being *Muricidea shilohensis*, *Turritella aequistriata*, *Corbula elevata*, *Venus ducatelli*, *Cytherea staminea*, and *Crassatellites melinus*. This, the dominant feature of the Calvert, is entirely lacking in the North Carolina deposits, and its absence can scarcely be explained by the mere difference in geographic position. The Choptank, which is intimately related to the Calvert, disappears before reaching the Maryland-Virginia line. "The second and equally important criterion is the presence, in great abundance, of typical St. Marys forms. Species which in Maryland are diagnostic of the upper Chesapeake are among the most profuse in the North Carolina formation. *Turritella variabilis* and *Pecten jeffersonius* and its varieties are possibly the most conspicuous examples, while *Scaphella mutabilis*, *Scalaspira strumosa*, *Ecphora quadricostata*, *Ensis directus*, *Phacoides cribrarius*, *Pandora crassidens*, and *Anomia simplex*, are far from rare.

"The St. Marys fauna of Maryland and that of North Carolina, while coexistent, are not identical. It is possible that the dissimilarity in the faunas may involve not only a range in latitude, but a slight chronologic range as well, and that the North Carolina formation may represent a slightly longer period of deposition than does the Maryland. There are certain species common in the North Carolina Chesapeake and in the later south Atlantic coast Tertiaries which in Maryland are confined to the Calvert and Choptank. Among these may be mentioned the common species *Venus rileyi*, *Asaphis centenaria*, *Nucula proxima*, *Divaricella quadrisulcata*, *Chama congregata*, *Tellina declivis*, *Tellina dupliniana*, and *Glycymeris subovata*. Their presence may, perhaps, be ascribable to a migration from the northeast—the probable direction of the advancing shore line. There is some evidence for believing that between late Calvert time and the initiation of the St. Marys in the north there was a shifting of the axis of elevation from approximately the latitude of the Virginia-North Carolina boundary towards the southward to the latitude of the present Hatteras axis. This would cause not only the submergence of the intermediate area, but would probably affect the ocean currents as well. By the lowering of the barriers to the northward free access would be given to the colder waters, while by an elevation to the southward an effective barrier might be raised against southern currents such as the Gulf Stream. The waters in the North Carolina area of deposition were not sufficiently cooled, however, to permit the existence of the strictly boreal forms, and only those species adapted to endure a wide range in temperature survived. Thus the migrants from the New Jersey fauna were cut out, while *Venus rileyi*, *Nucula proxima*, *Chama congregata*, etc., flourished in increasing numbers in the warmer waters of their new environment. In view of the individuality of the St. Marys fauna, it is not probable that a later migration to the northward took place, but rather that there was a contemporaneous evolution in Maryland and in North Carolina along slightly divergent lines."

YORKTOWN FORMATION.

The Yorktown formation overlies the St. Marys unconformably, both in Virginia and in North Carolina. It has been traced from river

basin to river basin across southern Virginia into North Carolina, where it has been found extending, as already described, over a wide area north of the Hatteras axis and where in the absence of the St. Marys formation it rests directly on the Eocene and Cretaceous formations. The materials of the Yorktown formation consist mainly of sands and shell marls, with a slight admixture of clay, the shell marl being generally distinguished from the marl beds of the St. Marys formation by the presence of large quantities of shell fragments. The character of the deposits, and particularly of the fragmental shell beds, indicates that the formation was in all probability laid down in shallow water within the area of wave action. The beds present many points of similarity to the Duplin deposits to the south of the Hatteras axis.

The fossils of the deposits are numerous and characteristic. Dr. Gardner has given the fauna much consideration and has prepared the following statement. She says:

"The preëminence of the beds at Yorktown, Virginia, as a standard of reference for the formation is due, not alone to their superiority as a collecting ground, but in equal measure to the fact that both phases of deposition are typically developed at this point—the yellow marl composed almost entirely of shells and shell fragments and containing a rich and diversified fauna, and the blue clay, also fossiliferous, but with a fauna much more restricted both in species and individuals. The former phase finds its best expression in North Carolina at Colerain Landing on the Chowan River and at Rock Landing on the Neuse, the latter at Mount Gould Landing and in the vicinity of Edenhouse Point on the Chowan. The fossiliferous deposits along the Chowan River are much less satisfactory than those along the York. At a few localities, especially in the vicinity of Tar Ferry and Colerain Landing, the material is well preserved, but farther down the river where the clay is best developed it is friable and the shells can with difficulty be separated from the matrix. The collection made at Rock Landing on the Neuse River is small, but is yielding a surprising number of species, many of which are still undetermined. The majority of the forms are minute, but there is among them a very fine species of *Macrocallista* 137 mm. in longitude. The profuseness of the yellow marl fauna is probably due in part to the fact that it includes not only the shallow-water forms, but also those that live between tides, while the fauna of the blue clay is characterized only by shallow-water species. The fauna as a whole is much richer than the underlying St. Marys, particularly in the gastropods and in the minute mollusca.

"Although there are very few forms that are confined strictly within the limits of the Yorktown, the general facies shows a distinct advance over the St. Marys and may be readily differentiated from it. The Pectens maintain their prominence, in some portions of the York River beds constituting almost the entire fauna. At these localities, *Pecten jeffersonius*, especially the variety *edgecombensis*, is the more abundant, but in many of the North Carolina deposits this species is superseded by *Pecten eboreus*. Among the Ostreas, *Ostrea sculpturata* is the most representative species, while *Ostrea compressi-*

rostra, which during the Chesapeake was almost equally abundant, occurs less frequently. The Arcas have increased in numbers and species. *Arca idonea*, however, seems to have become extinct. *Arca incile* persists, but is not plentiful. *A. lienosa*, though reported from the upper bed at Alum Bluff, makes its first appearance in the Middle Atlantic Coast in this formation. The Astartes change quite radically in general aspect. The St. Marys species *Astarte symmetrica* has not been reported from the formation. *Astarte exaltata* and *Astarte obruta* are rare or absent altogether. *A. undulata*, so abundant in the St. Marys, is on the decrease, while *A. concentrica* is much more prominent. Evolution is also evident among the Cardiums. *Cardium laqueatum* and *C. acutilaequetum* still continue, though in greatly diminished numbers. This period, however, marks the advent of two new species of this genus, *C. sublineatum* and *C. robustum*, the former profuse in the Pliocene, the latter still persistent. *Glycymeris americana* is more abundant than in the preceding epoch, while *Glycymeris subovata* continues to be a prominent form. The genus *Phacoides* is represented by a great number of species, all of which are widespread in their occurrence. These include *P. anodanta*, *P. crenulatus*, *P. radians*, and *P. trisulcatus*. *Venericardia granulata* is everywhere present, while the smaller species *V. tridentata* and *V. perplana* are less abundant. The smaller pelecypods are most of them undetermined, but it is certain that they will show a notable increase both in species and individuals.

"The Yorktown fauna in its occurrence at the type locality is conspicuous for the number of large and well-preserved Fulgurs. Though fragments are found at the localities along the Chowan and Neuse, conditions of deposition were not such as to allow their satisfactory preservation. *Turritella* is still richly represented by the species *variabilis* and its varieties. At Yorktown one bed is made up almost entirely of the variety *alticostata*. *Ecphora quadricostata* retains approximately the same relative position in the fauna as in the St. Marys. The *Buccinidae* and the *Nassidae* are somewhat more numerous. *Crepidula fornicata* and *Polynices duplicatus* are reported from nearly every locality where representative collections have been made, while *Crepidula aculeata*, *C. plana* and *C. heros* are more rare. *Calliostoma* is represented by eight species at Yorktown alone, but by few individuals. *Crucibulum* and *Fissuridea* are present in meager numbers. The smaller gastropods are quite numerous and include many late Miocene species. The gastropods as a whole do not, however, attain in North Carolina the same relative abundance which characterizes the Virginia Yorktown, especially in the vicinity of Suffolk.

"The Yorktown fauna is closely allied to that of the Duplin beds, and under the correlation of the latter will be quoted Dr. Dall's discussion of their relationship."

DUPLIN FORMATION.

The Duplin formation is in North Carolina the only representative of the Miocene to the south of the Hatteras axis, where it is found in isolated outcrops unconformably overlying the Cretaceous and Eocene deposits. This fragmentary occurrence is evidently due to erosion, the strata, as already pointed out, formerly covering in all probability wide areas throughout the region. The materials of the Duplin formation

are very similar to those of the Yorktown and consist largely of sands, arenaceous clays and shell marls, the latter much broken by wave action.

The fossils are numerous, the mollusca especially being well represented. The most extensive collections have been made from the Natural Well in Duplin County. There is also a large admixture of later forms, but the presence of many characteristic Miocene species forbids it being considered as later than Miocene. In South Carolina some of the beds in Darlington, Florence, and Sumter counties seem to belong to the same formation, although this cannot be known definitely to be the case until collections from those localities are more carefully studied. North of the Neuse River the Duplin formation does not seem to have been deposited, or, if originally present, has since been removed. The Yorktown formation may be its correlative, in part at least, though the more tropical character of the Duplin fauna is considered sufficient reason for not considering them entirely contemporaneous.

No fauna since collected approaches in profuseness and excellence of preservation that from the Natural Well and its environs. Outside of Duplin County the most promising fossiliferous localities are along the Lumber River in the vicinity of Lumberton and Fairmont in Robeson County. Very little determinative work, however, has been done upon these forms. The best collection from the Natural Well is that made by Mr. Burns and studied by Dr. Dall, which is now in the Smithsonian Institution. From it Dr. Dall determined 331 species of Mollusca exclusive of the new species. Of these there are many gastropods, mainly minute species of *Drillia*, *Marginella*, *Nassa*, and *Scala* and a slightly smaller number of pelecypods. The subtropical aspect of the fauna sharply separates it from the Yorktown, which is not known to occur south of the Hatteras axis and allies it to the succeeding warm-water Waccamaw. There are, however, distinctions which will be brought out in the discussion of the latter formation. Dr. Dall,[1] who has studied the fauna, says:

"A study of these [fossils from the Natural Well] indicates their general parallelism with the upper or Yorktown Miocene of Virginia, with which their deposition may have been partially synchronous. The fossil species are, however, largely distinct from those of the Yorktown beds and of a more tropical aspect. It is probable that in Miocene times, as at the present day, there was a difference in the marine faunas of the two regions, that at Yorktown and Suffolk being more allied to the subjacent temperate fauna of the older Miocene of Maryland and Virginia, while that in North Carolina contained more southern types. Yet even this seems hardly sufficient to account

[1] Wagner Free Institute Transactions, vol. 3, pt. 6, pp. 1598-1603.

for more than part of the difference. It is probable that with the elevation of the Gulf and Florida coasts, which closed the deposition of the cold-water Miocene on those shores, the changes in ocean currents which made the water warmer and invited the return of the subtropical fauna, banished at the end of the Oak Grove epoch, extended at least as far north as North Carolina. To this change I ascribe part of the new aspect of the Duplin fauna, which would thus be due to the combination of two factors."

WACCAMAW FORMATION.

The Waccamaw formation is limited to a relatively small portion of the North Carolina Coastal Plain and occurs in isolated areas to the south of the Hatteras axis. It overlies the older formations unconformably. Its areal distribution outside of North Carolina is not well known, although it has been found in adjacent parts of South Carolina. The fossils are distinctly later than the Duplin and contain a larger percentage of living species. The fauna and the materials, which are largely sands and shell marls, indicate that the beds were not laid down at a great depth. Similar deposits, if they existed north of the Hatteras axis, have been removed or have been buried by more recent strata. Dr. Gardner, who has been engaged in a study of the fauna, has prepared the following statement. She says:

"The fossil localities of the Waccamaw, as represented on the Cape Fear, though but few in number, are of unusual interest paleontologically. At Walker's Bluff and Neill's Eddy Landing collections have been made which show a fauna rich both in species and individuals. Though the determinative work is still far from complete, it is already evident that after the deposition of the Duplin a new element appeared in the marine life, making it very distinct from that of the Duplin beds. The prominent genera are much the same in both faunas, but the species of the Waccamaw are for the most part those characteristic of the Pliocene. Among the *Pectens*, *eboreus* is predominant, while the Miocene *jeffersonius* and its varieties are rare or altogether absent. The prominent *Arcas* are *limula*, especially the variety *platyura* so common in the Pliocene of the Caloosahatchie, *lienosa* and *adamsi*, all of which have been reported from the Miocene, but have not been known to flourish in that formation. *A. rustica* and *scalarina*, reliable diagnostics of the Pliocene, are present in very limited numbers. Of the *Dosinias*, *elegans* is the common species; of the *Mulinias*, *lateralis*. *Crassatellites undulatus*, hitherto supposed to mark the Miocene, is present, but only rarely, *gibbesii* being the dominant form. *Echinochama arcinella* and *Semele bella*, which make their appearance in the Yorktown, become increasingly numerous. The *Cardiums* present a distinctly Pliocene aspect, the Miocene *C. laqueatum* and *C. acutilaqueatum* being absent, while *C. robustum*, *C. sublineatum*, and *C. emmonsi* frequently occur. Among the *Corbulas* the later species, *barratiana*, *cuneata*, and *contracta* are the common ones, while *inaequalis* has become rare. The characteristic Miocene gastropod *Turritella variabilis* has been replaced by the more recent *Turritella subannulata*. One specimen of *Cancellaria carolinensis*, which has been supposed to be confined to the Miocene, was collected at Neill's Eddy

Landing. This, however, is a rare form limited in its range to the Cape Fear and west Florida. The much more widespread horizon-markers of the Miocene—*Ecphora quadricostata* and *Fulgur maximum* var. *incile*, both of which occur in Duplin County, have not been reported from the Waccamaw. *Pyrula papyratia*, a typical Caloosahatchie form, is not uncommon in the marl at Neill's Eddy Landing. *Caecum*, a genus which first appears in the Yorktown, is represented by three species—*floridanum*, previously reported from the Duplin beds, the Caloosahatchie Pliocene, and the Recent *cooperi* from the Cape Fear River, the Pliocene of Shell Creek, and the Recent; and *carolinianum* from the Caloosahatchie. *Dentalium attenuatum*, so abundant throughout the Miocene formation, seems to have disappeared. A large number of minute forms have been determined which have not previously been reported from below the Pliocene. They do not, however, furnish reliable criteria for correlation, since they would be overlooked in any but the most detailed examination of a fauna. The determinations are not sufficiently advanced at present to warrant a computation of the percentages of recent forms occurring in the Waccamaw along the Cape Fear, but it is confidently expected that more complete investigations will bear further testimony to the Pliocene age of the beds.

"The paleontologic evidence for assigning the Waccamaw beds to the basal Pliocene is equally convincing. The fauna represents an early Pliocene facies in which a few of the more stable Miocene forms have survived in greatly diminished numbers, while many of the species which are to become prominent in the later Pliocene, such as the *Arca rustica* and *A. scalarina*, are only just beginning to make their appearance. While it may seem to be a mixed fauna, this is more obvious in the lists than in the collections, for in the former all species are equally prominent, while in the latter the forms suggestive of the Miocene and of the middle and upper Pliocene are inconspicuous elements.

"The Waccamaw River beds of South Carolina were some years ago tentatively correlated by Dr. William H. Dall of the Smithsonian Institution with the Caloosahatchie marls, the accepted standard of comparison for the east coast Marine Pliocene. The Waccamaw was at that time supposed to represent a cooler-water fauna than the Caloosahatchie, and by this hypothesis their rather striking dissimilarity was explained. From Dr. Dall's work published in Bulletin 37 of the U. S. National Museum and from later unpublished data generously loaned to the writer, it appears that fully 94% of the Waccamaw species represented in the Recent seas are living south of the Hatteras axis. This would indicate that the Waccamaw fauna is distinctly subtropical in character and that the difference in the general facies is due to a range, not in latitude, but in time.

"The correlation of the North Carolina Waccamaw with that of South Carolina is based largely on the similarity of the fauna from the Cape Fear River localities to that from Tilley's Lake, Waccamaw River, the only undoubted Waccamaw material which has been convenient for consultation. The two faunas are not, however, identical, the former being the more profuse and diversified.

"Conditions along the Cape Fear at the advent of the Pliocene seem to have been unusually favorable for the development both of the individual and the species. *Pecten eboreus* attained an altitude of 136 mm. and an equal longitude

and *Oliva litterata* a maximum longitude of 82 mm. The old species present many and numerous variations and new species seem to be in the process of evolution.

"The facies presented in the Cape Fear region can be readily interpreted by the hypothesis which Dr. Paul Bartsch from his extensive study of the Pyramidellidae[1] believes to hold good—that it is the 'optimum condition that weakens specific bonds and tends to throw an organism into the so-called "state of flux."'

"It seems not improbable that, with the initiation of the Pliocene and the consequent warming of the waters, conditions for marine life became too favorable for the equilibrium of a fauna adapted to the cooler waters of the Miocene. Rapid development ensued, and these localities became a center of radiation of later Pliocene faunas. If this hypothesis be correct, a careful study of the fauna should reveal many precursors of later Pliocene forms. Some have already been found, and it seems rather certain that future study will yield results interesting both to the geologist and biologist."

Dr. William H. Dall of the Smithsonian Institution in the Wagner Free Institute Transactions, vol. 3, pt. 2, pp. 213-217, has given the results of his study of the Croatan fauna. Although small collections have subsequently been made from the Slocum's Creek locality, no determinative work has been done upon them. Dr. Dall's list includes 96 molluscan species. Among the diagnostic post-Waccamaw species may be noted *Plicatula gibbosa* Lamarck, *Arca pexata* Say, *Arca ponderosa* Say, *Arca campechiensis* Dillwyn, *Diplodonta subglobosa* C. B. Adams, *Ensis americana* Gld., *Rangia grayi* Conrad, *Labiosa canaliculata* Say, *Barnea costata* L., and *Urosalpinx cinereus* Say. Of the significance of their range he writes:

"In the case of the Croatan beds we find 35 uncharacteristic (Miocene to recent) species, with 6 new or doubtful forms. We have 2 characteristic Pliocene species, with 11 hitherto known as recent. Of the 55 with known range, 47 are known as Pliocene or younger, and 8 as of Pliocene or older horizons.

"The Croatan beds are obviously newer than those of the Waccamaw, yet when compared with the admitted Pleistocene beds of South Carolina, such as those of Simmon's Bluff, the presence on the Neuse of 41 out of 96 species which have not been known later than the Pliocene forbids us to regard the fauna as later than Pliocene."

LAFAYETTE FORMATION.

The Lafayette formation of North Carolina is poorly developed and the deposits are largely confined to a relatively narrow belt along the eastern margin of the Piedmont Plateau, where they are found, as has already been described, in somewhat isolated and highly dissected

[1]Pyramidellidæ of New England and the Adjacent Region. Proc. Bos. Soc. Nat. Hist., vol. 34, No. 4, p. 91.

patches, resting for the most part directly on the crystalline rocks. In the absence of fossils, physical criteria alone are available for the correlation of the Lafayette formation.

The materials are very similar in character to those found in deposits regarded as Lafayette, both to the north and south of North Carolina. The structure and composition of the strata are characteristic, and when to these is added the position of the beds at a high elevation along the eastern margin of the Piedmont belt, it is evident that the formation can only be correlated with the deposits regarded as Lafayette in adjacent areas.

Although the remnants of the formation in North Carolina are so dissected and isolated as to make it impossible to recognize the ancient terraced surface which is still found preserved in other districts and which can oftentimes be followed over considerable areas in Virginia and Maryland, still the strata are so similar to the Lafayette elsewhere and so unlike the deposits of earlier or later formations that there seems little reason to doubt that they represent the great Lafayette formation described as extending throughout the Atlantic and Gulf districts.

The age of the Lafayette formation is in much doubt. From its known stratigraphic relations it is younger than the latest Miocene beds and probably younger than the marine Pliocene, likewise. These earlier beds were apparently subjected to a long interval of erosion before the deposition of the Lafayette began. Again, after the close of the Lafayette, it is probable that an extensive epoch of erosion occurred before the Columbia deposits of Pleistocene age were laid down. The position of the Lafayette is therefore between the marine beds of Pliocene age and the oldest deposits of recognized Pleistocene age. The Lafayette formation is therefore, in all probability, of late Pliocene or early Pleistocene age. The consensus of opinion hitherto has been in favor of the former interpretation, but in the absence of fossils it is practically impossible to reach a positive conclusion. It is evident that more adequate evidence must be secured before the question can be regarded as settled. In any event, it seems certain that all of the materials referred by geologists to the Lafayette are not of the same age, and since Berry has shown[1] that the type locality in Lafayette County, Mississippi, is of Eocene age, it would seem that a new name was demanded for the high-level surficial deposits of the Atlantic border which have hitherto been referred to the Lafayette and which were earlier named Appomattox by McGee.

[1]Berry, Jour. Geol., vol. 19, 1911, pp. 249-256.

TABLE SHOWING CORRELATION OF MIOCENE AND PLIOCENE FORMATIONS.

	Long Island and Southern New England.	New Jersey.	Maryland and Delaware.	Virginia.	North Carolina.
Pliocene			"Lafayette"	"Lafayette"	"Lafayette." Waccamaw.
Miocene				Yorktown	Yorktown-Duplin.
			St. Marys	St. Marys	St. Marys.
	Long Island and Martha's Vineyard deposits.	Cohansey and Beacon Hill.	Choptank		
		Kirkwood	Calvert	Calvert	

COHARIE FORMATION.

The Coharie formation, like the Lafayette formation, can only be correlated on the basis of physical criteria. The Coharie terrace, which is best developed in the more southern counties of the belt, where it occupies a position below the Lafayette and above the Sunderland, gradually disappears northward. The Coharie terrace has been traced southward into South Carolina, but its extent and relations are imperfectly known.

The age of the Sunderland and later terraces has been generally recognized as Pleistocene, and it is probable that the Coharie should also be regarded as of Pleistocene age. The fossil leaves found in the Sunderland farther north belong mostly to living species, while the relatively small physical changes that have occurred indicate that the deposits cannot be older than Pleistocene. Whether they represent the earliest phase of Pleistocene deposition has not been settled, and cannot be until the age of the Lafayette formation is finally determined.

SUNDERLAND FORMATION.

The Sunderland formation is more extensively developed than the Coharie and its surface has suffered less from erosion than has the former. Its location both in reference to higher and lower terraces and the fact that it can be traced northward into the Sunderland formation of Maryland shows that it must be regarded as the equivalent of the latter. The escarpment separating the Sunderland terrace from the Wicomico can be clearly traced from North Carolina across Virginia into Maryland, where the relations were first observed and described.

The materials and surface characteristics of the Sunderland terrace

in North Carolina are likewise similar to those of the Sunderland of more northern areas, the amount of erosion being much more extensive than in the lower-lying and later Wicomico terrace.

WICOMICO FORMATION.

The Wicomico formation is correlated with the formation so named in Virginia and Maryland because it can be traced with unimportant breaks all the way from North Carolina across Virginia and Maryland, into the valley of the Delaware, enwrapping the older Pleistocene deposits and extending as reëntrants into the older formations. Furthermore, throughout this long distance it maintains much the same elevation with respect to sea level. Its surface has also suffered much less from erosion than the older formations, the physiographic features, therefore, presenting much the same appearance throughout the entire area. The materials likewise are on the whole less decayed.

The few plant fossils found in the Wicomico formation belong essentially to living species, although in a few instances they seem to be ancestral types that have since become differentiated into those living to-day in the sand barrens and in the upland country. The differences, however, are so slight that there is no question of the flora as a whole being referred to late Pleistocene time.

CHOWAN FORMATION.

The Chowan formation can be followed as a terrace enwrapping the Wicomico terrace across Virginia into Maryland, where it and the next lower terrace have been described as the Talbot formation. In the extreme southeastern part of Maryland not far from the ocean front a low escarpment is described[1] extending from Berlin to Newark, which may perhaps represent the separation between two subordinate or secondary terraces within the Talbot terrace. These two subordinate plains are possibly the Chowan and Pamlico plains, which are much more extensively developed to the southward and which have been traced across North Carolina into Virginia, the lower terrace gradually narrowing until it becomes an insignificant feature in southeastern Maryland.

The Chowan terrace has the same general elevation above tide as the main body of the Talbot formation farther north, its materials and surface features likewise being similar. The terrace has been but little dissected throughout the entire area, swamps and other evidences of

[1]Md. Geol. Survey, Pliocene and Pleistocene, 1906, p. 75.

imperfect drainage being common, although this feature, first prominently occurring on the Wicomico, becomes even more marked in the case of the still younger Pamlico terrace.

PAMLICO FORMATION.

The Pamlico formation is the latest and lowest of the Pleistocene terrace formations and can be traced as a broad lowland of slight elevation into southern Virginia, gradually narrowing northward until it becomes reduced in Maryland to a limited area in the southeastern portion of that State, where it was recognized, but described as a member of the Talbot formation. As already stated, the Chowan and Pamlico formations have been combined in Maryland and Virginia under the name of the Talbot formation.

The surface of the Pamlico formation everywhere gives evidence of recent origin and has been but little modified by the forces of erosion. The fossil shells as well as leaves show but few differences from living species, and the formation evidently represents a very late phase of Pleistocene deposition.

TABLE SHOWING CORRELATION OF PLEISTOCENE FORMATIONS.

Delaware and Maryland.	Virginia.	North Carolina.
Talbot	Talbot	Pamlico. Chowan.
Wicomico	Wicomico	Wicomico.
Sunderland	Sunderland	Sunderland.
		Coharie.

RECENT FORMATIONS.

The Recent formations consist of beaches, sandbars, sand spits, sand dunes, etc. The Recent deposits are found chiefly bordering the coast, the estuaries, and the streams. Beaches of varying character line the coast of the sea and estuaries, and sandbars and spits are found where the currents of the present day have built up such deposits. The sand dunes are found scattered at various points along the coast. Similar dunes are found farther to the northward in Virginia and Maryland, although of far less extent than in North Carolina. Along the streams flood plains have been developed and along the hillsides the wash of the land has caused much change in its configuration.

Similar Recent formations, with certain differences based on the un-

derlying deposits and climatic changes, are found throughout the coastal border. Very few fossils are found, although here and there shells of marine organisms and fossil plants are entombed in the deposits.

COMPARATIVE TABLE OF GEOLOGICAL FORMATIONS.

			Delaware and Maryland.	Virginia.	North Carolina.	Alabama.	Approximate European Equivalents.
QUATERNARY	Recent		Recent	Recent	Recent	Recent	Alluvium.
	Pleistocene	Columbia			Pamlico		
			Talbot	Talbot	Chowan		
			Wicomico	Wicomico	Wicomico	Columbia	Diluvium.
			Sunderland	Sunderland	Sunderland		
					Coharie		
TERTIARY	Pliocene						Sicilian.
			"Lafayette"	"Lafayette"	"Lafayette"	"Lafayette"	Astian.
					Waccamaw	Not named	Plaisancian.
	Miocene	Chesapeake		Yorktown	Yorktown and Duplin.	Pascagoula	Pontian.
			St. Marys	St. Marys	St. Marys		Tortonian.
			Choptank				Helvetian.
			Calvert	Calvert			Burdigalian.
	Oligocene						Aquitanian.
						Apalachicola	Tongrian.
						Vicksburg	Ligurian.
	Eocene	Pamunkey			Castle Hayne	Jackson	Bartonian.
					Trent	Claiborne	Lutetian.
			Nanjemoy	Nanjemoy		Wilcox	Sparnacian.
			Aquia	Aquia			Ypresian.
						Midway	Thanetian.
CRETACEOUS	Upper Cretaceous		Rancocas				Danian.
			Monmouth		Peedee	Ripley, Selma	Senonian.
			Matawan	In well borings	Black Creek	Eutaw	Turonian.
			Magothy			Tuscaloosa	
			Raritan				Cenomanian.
	Lower Cretaceous	Potomac	Patapsco	Patapsco			Albian.
							Aptian.
			Arundel			Lower Cretaceous. (Earlier referred to "Tuscaloosa.")	Barremian.
			Patuxent	Patuxent	Patuxent		Neocomian.

PART II

THE WATER RESOURCES OF THE COASTAL PLAIN OF NORTH CAROLINA

BY L. W. STEPHENSON AND B. L. JOHNSON

AND

THE QUALITY OF SOME WATERS OF THE COASTAL PLAIN OF NORTH CAROLINA

BY HORATIO N. PARKER.

THE WATER RESOURCES OF THE COASTAL PLAIN OF NORTH CAROLINA.

By L. W. STEPHENSON and B. L. JOHNSON.

CHAPTER I.

HISTORICAL REVIEW.

Previous to the investigations furnishing the materials for this report very little systematic study had been made of the water resources of the Coastal Plain of North Carolina, or of the conditions governing their availability for domestic and manufacturing purposes. The volume of the literature on the subject is therefore small, and with a few exceptions consists of brief references to or descriptions of springs, wells, municipal water supplies, etc. On the following pages will be found a brief review of the more important contributions, and in the bibliography which follows references to the less important contributions are included.

Denison Olmsted[1] prophesied in 1825 that if means could be found to penetrate the deposits of the Coastal Plain to depths of 100 feet or more, much finer water could be obtained than that furnished by shallow wells.

The first record of an attempt to obtain water for domestic purposes by deep boring is that of a well at Edenton described by Elisha Mitchell[2] in 1827. Apparently no water was obtained.

The underground circulation in the limestones (Eocene) underlying Jones, Duplin, and Onslow counties, the occurrence of sinks in this limestone, and the issuance of springs from its cavities are briefly described by Prof. W. C. Kerr[3] in his report of 1875.

[1] "Report on the Geology of North Carolina, conducted under the direction of the Board of Agriculture," Part II, November, 1825.

Papers on agricultural subjects and Professor Olmsted's Report on the Geology of North Carolina, published by order of the Board of Agriculture, Part II, pp. 87–141, 8 vo., Raleigh, 1827.

[2] "Report on the Geology of North Carolina, conducted under the direction of the Board of Agriculture," Part III, November, 1827, 27 pp.

[3] "Report of the Geological Survey of North Carolina." Vol. 1, Raleigh, 1875, 325+120 pp.

In his report on the mineral springs of the United States, published in 1886, A. C. Peale[4] includes in his list of mineral springs of North Carolina a number from the Coastal Plain counties. Analyses are given of the water from a number of them.

In his report of 1893, Prof. J. A. Holmes[5] discusses the liability to pollution of the waters obtained from shallow wells and springs and lays particular stress upon the probability of contamination in the case of water from such sources in the flat Coastal Plain regions. He discusses very briefly the probability of obtaining potable waters from deeper sources in many parts of the Coastal Plain.

The first systematic account of the artesian resources of the Coastal Plain is that of N. H. Darton[6] published in 1896. The geologic conditions in North Carolina are briefly summarized and a list is given of 39 wells ranging in depth from 50 to 495 feet. This is followed by a brief account of the artesian conditions in each of the Coastal Plain counties so far as known at the time of the publication of the report. The data on which the report is based are credited to Prof. J. A. Holmes, who was at that time State Geologist of North Carolina.

The report of the North Carolina Board of Health for 1895-'96[7] includes a description of the source of public supply at Fayetteville (pp. 67-68). In the same report (pp. 177-180) Dr. Julian M. Baker discusses the liability to pollution of shallow well waters, and recommends the use of deep artesian wells where possible.

Professor Holmes[8] in his report of 1898 mentions the desirability of obtaining artesian water supplies in the Coastal Plain. He also refers briefly to the unsuccessful attempt of the Clarendon Waterworks Company to obtain potable water by drilling to a depth of 500 feet, and to successful attempts at Hope Mills, Cumberland County, and in Robeson, Bladen, Columbus, Craven, Hyde, Edgecombe, New Hanover, and other counties. He explains the difficulty of predicting whether or not good waters can be obtained at given localities, and gives reasons why failures have in places been experienced.

The same author, the following year, 1899,[9] gives a full account of the second unsuccessful attempt of the Clarendon Waterworks Company at Wilmington to obtain an artesian supply of potable water by

[4]Bull. U. S. Geol. Survey, No. 32, 1886, 235 pp.

[5]First Biennial Report of the State Geologist (of North Carolina), 1891–1892. Raleigh, 1893, 111 pp.

[6]Bull. U. S. Geol. Survey, No. 138, 1896, 232 pp.

[7]"Municipal Water Supplies." Sixth Biennial Report of the North Carolina Board of Health, 1895–1896. Winston, 1897, pp. 56–84.

[8]Biennial Report of the State Geologist (of North Carolina), 1897–1898. Raleigh, 1898, 28 pp.

[9]Jour. Elisha Mitchell Sci. Soc., July–Dec., 1899, pp. 67–70. Science, n. s., vol. 2, 1900, pp. 128–130.

deep drilling. The well was sunk entirely through the deposits of the Coastal Plain and entered underlying granite at a depth of 1,109 feet. Flowing artesian horizons were encountered at various depths from 379 feet to the granite bedrock, but in each case the content of sodium chloride (common salt) and other salts was so high as to render the water unfit for use.

In the report of the North Carolina Board of Health for 1897-'98, the public supplies at Goldsboro, Wilson, New Bern, Wilmington, and Fayetteville are briefly discussed. Analyses of many well and spring waters are given. The report of this board for 1899-1900[10] gives many analyses of well and spring waters of the Coastal Plain and describes the sources of public supply of a number of the larger towns of this region.

In its report for 1901-1902[11] is included information concerning the public supplies of a number of the larger eastern towns and cities, similar to that furnished by the preceding reports.

The geologic and artesian conditions of the North Carolina Coastal Plain were briefly described by M. L. Fuller[12] in 1905, and a list of 39 deep wells given.

The State Board of Health in its report for 1903-1904[13] quotes in full a law passed by the General Assembly of 1903, entitled "An act to protect water supplies."

In 1906, M. L. Fuller[14] described several wells near Wilmington and Southport which when first drilled yielded a saline water, but which, after flowing or being pumped for a short time, became fresh. He concludes that a well should not necessarily be regarded as a failure if the first water it yields is of a saline character.

In 1906 the records of three North Carolina wells were given by M. L. Fuller and Samuel Sanford,[15] the first at Kinston, Lenoir County, the second at Fort Caswell, New Hanover County, and the third at Pinehurst, Moore County.

In 1907, Gerald McCarthy[16] described briefly the artesian conditions existing in eastern North Carolina. He gives directions as to how to secure artesian supplies and discusses means for keeping in order wells that have already been drilled.

[10]Eighth Biennial Report of the North Carolina Board of Health, 1899–1900. Raleigh, 1900, pp. 99–126.

[11]Ninth Biennial Report of the North Carolina Board of Health, 1901–1902. Raleigh, 1902, pp. 83–103.

[12]North Carolina Water-supply and Irrigation Paper, No. 114, U. S. Geol. Survey, 1905, pp. 136–139, 1 fig.

[13]Tenth Report of the North Carolina Board of Health, 1903–1904.

[14]U. S. Geol. Survey, Water Supply and Irrigation Paper, No. 160, 1906, pp. 96–99.

[15]Bull. U. S. Geol. Survey, No. 298, 1906, pp. 245–246.

[16]Bull. of North Carolina Board of Health, vol. 22, No. 1, April, 1907, pp. 1–14, 6 figs.

BIBLIOGRAPHY OF UNDERGROUND WATERS.

ABERT, S. T.—*Survey of a Line to Connect the Waters of the Neuse and Cape Fear Rivers in North Carolina, and of a Line to Connect the Waters of Norfolk Harbor, in Virginia, with the Waters of the Cape Fear River at or Near Wilmington, N. C.* Senate Ex. Doc., No. 35, 44th Congress, 1st Session.

Includes records of borings at Norfolk, Va., Edenton, N. C., Clubfoot and Harlowe's Creek Canal in Beaufort and Carteret counties, N. C. (pp. 16-18).

BAKER, JULIAN M.—"*Malaria and Its Prevention in Eastern Carolina.*" Sixth Biennial Report of the North Carolina Board of Health, 1895-1896. Winston, 1897; pp. 177-180.

Underground water conditions briefly described.

BARTRAM, WILLIAM.—*Travels Through North and South Carolina, Georgia, East and West Florida, the Cherokee Country, etc.* Philadelphia, 1791. 522 pp., 6 pl. and map. London ed., 1794.

Notes chalybeate character of water issuing from laminated beds at Ashwood on the Cape Fear River, N. C. (pp. 474-475).

DALL, W. H., and HARRIS, G. D.—*Neocene.* Bull. U. S. Geol. Survey, No. 84, 1892, 349 pp.

Describes the "natural well" in Duplin County, N. C. (pp. 72-73).

DARTON, N. H.—*Artesian Well Prospects in the Atlantic Coastal Plain Region.* Bull. U. S. Geol. Survey, No. 138, 1896, 232 pp.

The conditions in North Carolina are discussed by counties. Geologic section and several well records given (pp. 190-207).

————————*Norfolk Folio. Virginia-North Carolina.* Geol. Atlas of U. S., folio No. 80. U. S. Geol. Survey, 1902, 4 pp.

Contains a brief reference to the underground water conditions in the North Carolina portion of the Norfolk quadrangle.

DARTON, N. H.—*Preliminary List of Deep Borings in the United States, Part II (Nebraska to Wyoming).* Water-supply and Irrigation Paper, No. 61, U. S. Geol. Survey, 1902, 67 pp.

Contains data regarding deep wells at Wilmington, Selma, and Wrightsville, N. C. (p. 20).

————————*Preliminary List of Deep Borings in the United States.* Second edition, with additions. Water-supply and Irrigation Paper, No. 149, U. S. Geol. Survey, 1905. 175 pp.

Contains data regarding wells at Sanford, Wilmington, Selma, and Wrightsville, N. C. (p. 94).

EMMONS, EBENEZER—*North Carolina Geological Survey, Part II. Agriculture.* Containing descriptions, with many analyses, of the soils of the swamp lands. Raleigh, 1860, 95 pp.

States that Hyde County is only a few feet above tide; "too few to give depth to wells, and hence, water for cooking is supplied mainly from cisterns resting on the ground" (p. 27). Gives a few brief descriptions of mineral springs and well waters near Raleigh (pp. 92-95).

FULLER, M. L.—*North Carolina.* Water-supply and Irrigation Paper, No. 114, U. S. Geol. Survey, 1905, pp. 136-139, 1 fig.

Describes briefly the artesian conditions of the Coastal Plain and gives list of wells. Lists the principal mineral springs and publications on underground waters of the State.

FULLER, M. L.; LINES, E. F., and VEATCH, A. C.—*Record of Deep-well Drilling for 1904.* Bull. U. S. Geol. Survey, No. 264, 1905, 106 pp.

Gives depth, driller, and year completed of city well, Kinston, N. C. (pp. 60-61).

——————*Bibliographic Review and Index of Papers Relating to Underground Waters, Published by the U. S. Geol. Survey, 1879-1904.* Water-supply and Irrigation Paper, No. 120, U. S. Geol. Survey, 1905, 128 pp.

References to the underground waters of North Carolina are indexed under North Carolina.

FULLER, M. L.—*Instances of Improvement of Water in Wells.* U. S. Geol. Survey, Water-supply and Irrigation Paper, No. 160, 1906, pp. 96-99.

Descriptions are given of several wells near Wilmington and Southport, N. C., which, yielding saline water at first, have later become fresh. Concludes that a well should not necessarily be regarded as a failure if only salt water is obtained at the start.

FULLER, M. L.; CLAPP, F. G.; JOHNSON, B. L.—*Bibliographic Review and Index of Underground Water Literature Published in the United States in 1905.* Water-supply and Irrigation Paper, No. 163, U. S. Geol. Survey, 1906, 130 pp.

Publications relating to North Carolina underground waters indexed under North Carolina.

FULLER, M. L., and SANFORD, SAMUEL—*Record of Deep-well Drilling for 1905.* Bull. U. S. Geol. Survey, No. 298, 1906, 299 pp.

Records are given of deep wells at Kinston, Pinehurst, and Fort Caswell, N. C. (pp. 245-246).

FULLER, M. L.—*Summary of the Controlling Factors of Artesian Flows.* U. S. Geol. Survey Bull., No. 319, 1908, p. 18.

Notes the occurrence of originally included sea waters in beds penetrated in wells near Wilmington, N. C.

FULTON, HAMILTON—*Report of Sundry Surveys made by Hamilton Fulton, Esq., State Engineer, agreeably to certain instructions from Judge Murphey, Chairman, etc., and Submitted to the General Assembly at their Session in 1819.* Raleigh. Printed by Thomas Henderson, 1819.

Locates the "poplar springs" near the Lumber River at the lowest point of the ridge between that river and the Cape Fear at Fayetteville (p. 35).

HODGE, JAMES T.—*Observations on the Secondary and Tertiary Formations of the Southern Atlantic States.* Amer. Jour. Sci. (1st ser.), vol. 41, 1841, pp. 332-344. Also, in "Reports of the First, Second, and Third Meetings of the Association of American Geologists and Naturalists, 1840-1842." Boston, 1843; pp. 94-111.

Describes the "natural wells" in Duplin County, N. C. Also mentions the issuing of springs from the limestone in Jones County.

HOLMES, J. A.—*First Biennial Report of the State Geologist (of North Carolina), 1891-1892.* Raleigh, 1893; 111 pp.

Discusses the liability to pollution of the shallow wells in the Coastal Plain. Briefly summarizes the results obtained by the State Geological Survey in the investigation of the artesian condition in the Coastal Plain of North Carolina (pp. 13-14, 23).

HOLMES, J. A.—*Biennial Report of the State Geologist (of North Carolina), 1893-1894.* Raleigh, 1894; 15 pp.

Brief reference to the work of the North Carolina Geological Survey on the artesian waters of the Coastal Plain of that State (p. 11).

HOLMES, J. A.—*Biennial Report of the State Geologist (of North Carolina), 1895-1896.* Raleigh, 1896; 17 pp.

Brief reference to the work of the North Carolina Geological Survey on the artesian waters of the Coastal Plain of that State (p. 14).

HOLMES, J. A.—*Biennial Report of the State Geologist (of North Carolina), 1897-1898.* Raleigh, 1898; 28 pp.

Notes the examination of the mineral springs of the State by the N. C. Geological Survey (pp. 19-20). The artesian water supplies of the Coastal Plain are briefly considered, references being made to several wells (pp. 20-22).

HOLMES, J. A.—*The Deep Well at Wilmington, N. C.* Jour. Elisha Mitchell Sci. Soc., July-Dec., 1899, pp. 67-70. Also given in Science, n. s., vol. 11, 1900, pp. 128-130.

Gives considerable data regarding the flowing salt well of the Clarendon Waterworks Company, Wilmington, N. C.

HOLMES, J. A.; VON HERRMAN, C. F.; SWAIN, G. F.—*Water-power in North Carolina As Influenced by Physiographic Conditions.* Bull. No. 8, N. C. Geol. Survey, 1899, Part I, pp. 17-88.

Brief reference to the springs in the sandhills of North Carolina (p. 79).

HOLMES, J. A.—*Biennial Report of the State Geologist (of North Carolina), 1899-1900.* Raleigh, 1900; 20 pp.

Describes briefly the work of the members of the North Carolina Geological Survey in the examination of the mineral waters of the State and in the investigation of the artesian water supplies in the Coastal Plain of North Carolina (p. 14).

HOLMES, J. A.—*Biennial Report of the State Geologist (of North Carolina), 1901-1902.* Raleigh, 1902; 15 pp.

Notes use of topographic maps of the eastern counties of North Carolina in the study of the underground water conditions (p. 12).

HOLMES, J. A.—*Biennial Report of the State Geologist (of North Carolina), 1903-1904.* Raleigh, 1905; 32 pp.

Notes the need of topographic maps in the study of the underground water supplies in the Coastal Plain of North Carolina (p. 17).

KERR, W. C.—*Report of the Geological Survey of North Carolina.* Vol. 1, Raleigh, 1875; 325+120 pp.

Brief description of the underground circulation in the limestones underlying Jones, Duplin, and Onslow counties, and the occurrence of sinks and limestone springs in the counties noted (pp. 12-13). Analyses of several well and spring waters are given (pp. 306-311).

LAWSON, JOHN—*A New Voyage to Carolina:* containing the exact description and natural history of that country, together with the Present State thereof and a Journal of a Thousand Miles Travel'd through several Nations of Indians. Giving a particular account of their customs, manners, etc. London, 1709.

Describes wood encountered at a depth of 26 feet in digging a well. Refers the burial of the wood to the "deluge" (pp. 169-170).

LUDLOW, J. L.—*(Municipal Water Supplies) Ninth Biennial Report of the North Carolina Board of Health, 1901-1902.* Raleigh, 1902; pp. 83-103.

Considerable data regarding public supplies in the Coastal Plain of North Carolina given.

MCCARTHY, GERALD—*Ground and Deep Waters of North Carolina.* Bulletin of North Carolina Board of Health, Vol. 22, No. 1, April, 1907, pp. 1-14, 6 figs.

Artesian conditions in the Coastal Plain described. Several analyses of Coastal Plain well waters given.

MCCARTHY, GERALD—*The Purification of Public Water Supplies.* Pamphlet, 8 pp., 1907.

Gives the standard of quality used by the North Carolina State Laboratory of Hygiene. Compares the death rate from typhoid fever in towns classified according to kinds of water supply. Discusses methods of purifying and filtering water.

MCCARTHY, GERALD—*Report of Biologist; Tenth Report, North Carolina Board of Health,* pp. 31-34.

States that five water companies in the State obtain their supply from deep wells, and urges the general abandonment of shallow wells for deep wells.

MITCHELL, ELISHA—*Report on the Geology of North Carolina,* conducted under the direction of the Board of Agriculture. Part 3, Nov., 1827, 27 pp.

Source of Lumber River in sandhill springs noted (p. 9). Natural well in Duplin County described (p. 13). Section of boring at Edenton, N. C., given (p. 13).

MITCHELL, ELISHA—*On the Character and Origin of the Low Country of North Carolina.* Amer. Jour. Sci., 1st ser., vol. 13, 1828, pp. 336-347.

Describes the natural well in Duplin County (p. 339).

NEWELL, F. H.—*Report of Progress of the Division of Hydrography for the Calendar Year 1895.* Bull. U. S. Geol. Survey, No. 140, 1896, 356 pp.

Mentions the springs of the sandhill region of North Carolina (p. 65).

NEWELL, F. H.—*Report of Progress of Stream Measurements for the Calendar Year 1902.* Part II, southern Atlantic, eastern Gulf, and Great Lakes drainage. Water-supply and Irrigation Paper, No. 83, U. S. Geol. Survey, 1893, 304 pp.

Discusses the storage of water and possible loss by subterranean flow from sand belt of the Cape Fear basin, N. C. (pp. 30, 60).

N. C. BOARD OF HEALTH—"*Municipal Water Supplies.*" Sixth Biennial Report of the North Carolina Board of Health, 1895-1896. Winston, 1897; pp. 56-84.

The source of the public supply of Fayetteville is described; on page 67 several analyses are given of Coastal Plain well waters.

N. C. BOARD OF HEALTH—"*The Public Water Supplies of the State.*" Seventh Biennial Report of the North Carolina Board of Health, 1897-1898. Raleigh, 1899; pp. 44-78.

Gives data regarding the public supplies at Goldsboro, Wilson, New Bern, Wilmington, and Fayetteville. Many chemical analyses of well and spring waters are given.

N. C. BOARD OF HEALTH—"*Municipal Water Supplies.*" Eighth Biennial Report of the North Carolina Board of Health, 1899-1900. Raleigh, 1900; pp. 99-126.

Several of the public supplies in the Coastal Plain are described, with analyses. Many analyses are given of well and spring waters of the Coastal Plain.

N. C. BOARD OF HEALTH—*Tenth Report, 1903-1904.* State laws of North Carolina relative to pollution of wells and springs given (p. 79).

OLMSTED, DENISON—*Letter dated June, 1821, to Board of Internal Improvements.* Annual Report of the Board for Public Improvements of North Carolina to the General Assembly, November 26, 1821, together with Mr. Fulton's reports to the board and other papers in relation to the improvements of the State. Raleigh, 1821.

Mr. Olmsted describes the advantages which would result from a study of the geology of the State. States that "The nature of mineral springs already celebrated might be investigated, and others which appear to be valuable made known" (pp. 65-67).

OLMSTED, DENISON—*Report on the Geology of North Carolina,* conducted under the direction of the Board of Agriculture. Part II. Nov., 1825.

Papers on agricultural subjects and Professor Olmsted's report on the geology of North Carolina, published by order of the Board of Agriculture. Part 2, Raleigh, 1827, pp. 87-141, 8 vo. Reviewed in Amer. Jour. Sci. (1st ser.), vol. 14, 1828, pp. 230-251.

Gives record of materials passed through in Clubfoot and Harlowe Spring Canal (pp. 88-89). Brief reference to mineral springs in Wayne and Craven counties (p. 101). Also notes that the wells of the Coastal Plain district are rarely if ever walled, the compactness of the clays forming the natural walls preventing caving. Prophesies a much finer kind of water if means could be found to penetrate to a depth of a hundred feet or more (p. 101).

PEALE, A. C.—*Natural Mineral Waters of the United States.* Fourteenth Ann. Rept. U. S. Geol. Survey, 1892-93, Part 2, pp. 49-88.

Gives the flow of the Alum and Panacea Springs in North Carolina (p. 60). A list of the mineral spring resorts of North Carolina is also given (pp. 85-86).

PEALE, A. C.—*Lists and Analyses of the Mineral Springs of the United States.* Bull. U. S. Geol. Survey, No. 32, 1885, 235 pp.

Gives the analyses and data regarding flow and temperature of several springs in the Coastal Plain of North Carolina (pp. 74-78).

PRATT, JOSEPH HYDE—*The Mining Industry in North Carolina During 1907, with a Special Report on the Mineral Waters.* Economic Paper No. 15, N. C. Geol. and Economic Survey, 1908, 176 pp.

Gives descriptions, analyses, and data regarding rate of flow and temperature of several springs in the Coastal Plain region of North Carolina (pp. 74-146).

SWAIN, GEORGE F., and HOLMES, J. A.—*Water-power in North Carolina East of the Blue Ridge.* Bull. No. 8, N. C. Geol. Survey, 1899, pp. 89-230.

Notes occurrence near Goldsboro of several small spring streams (p. 125). Storage of water in the sandhills and its value in regulating flow of the sandhill streams discussed, using Rockfish Creek as an example (pp. 138-140).

SURFACE WATERS.

The investigations furnishing the data for this report were not carried on with a view to determining the availability of surface waters as a source of supply for domestic or other purposes. In the separate county reports, however, in cases where stream waters are now being utilized for municipal supplies, they are discussed briefly. It may be stated that the use of such waters is practicable in almost all parts of the Coastal Plain. If used, however, except under the most favorable natural conditions, they should be subjected to processes of filtration designed to remove suspended matter, including organic matter of whatever origin, but especially that derived from sewage.

UNDERGROUND WATERS.

SOURCES OF THE UNDERGROUND WATERS.

Rainfall is the source of the circulating underground waters of the region under consideration. It is probable that, because of the low relief and the prevalence of sandy soils in the North Carolina Coastal Plain, 85 per cent or more of the water which falls upon the surface is absorbed by the soil and, with the exception of a relatively small amount which is appropriated by the roots of plants, finds its way downward into the underlying materials. The remaining portion which does not take this course either runs off to the sea by gravity on the surface or passes by evaporation into the atmosphere.

In the deeply buried beds of the Coastal Plain, at depths exceeding in different places from 250 to 500 feet, the included waters probably were not derived directly from rainfall by downward percolation from the surface, but constitute originally included sea waters which were

confined in the deposits at the time they were being laid down on the bottom of the sea. These deep-seated waters do not circulate, due to conditions the attempted explanation of which will be given later, but have remained practically at a standstill since the time of their inclusion.

PRINCIPLES AND CONDITIONS CONTROLLING THE STORAGE AND CIRCULATION OF UNDERGROUND WATERS OF THE NORTH CAROLINA COASTAL PLAIN.[1]

The materials of the Coastal Plain of North Carolina consist of a great series of sedimentary deposits, for the most part unconsolidated, which rest upon a gently sloping surface of ancient rocks. In the Piedmont Plateau region the latter form the surface materials and along its eastern border have elevations of from 400 to 500 feet. Their surface here dips to the eastward beneath the sediments of the Coastal Plain, forming a gentle slope which passes gradually to greater and greater depths in the coastward direction. Along the immediate coast this surface lies at depths of 1,000 feet and more below sea level. A contour map of the buried surface of the basement rocks, with contour intervals of 500 feet, has been prepared by B. L. Johnson. (See map, Plate XXIX.) Little is known of its extension out beneath the ocean, but it probably reaches at least as far as the edge of the Continental shelf. By referring to the geologic section (Plate XXX, opposite p. 343), it will be observed that the sediments of the Coastal Plain resting upon this rock surface consist of a succession of clay, sand, and in part of limestone beds which dip at a slight angle to the surface. The landward edges of the lower beds come almost to the surface immediately to the east of the Piedmont border, and the overlying beds likewise come close to the surface at points successively farther from the Piedmont and nearer to the coast in the ascending order of their stratigraphic positions. Their upper edges appear to have been planed or beveled off, and the plain thus formed to have been subsequently covered by nearly horizontal surficial beds of loam, sand, gravel, and clay.

Water which falls upon the surface as rain is absorbed by the loams and sands, passes through them by gravity, and either enters the underlying inclined beds or moves off laterally and escapes as springs along the valley slopes. If these inclined beds led to a place of escape at their lower ends the water would continue to gravitate downward, fol-

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[1]The reader is referred to the following papers treating of general artesian conditions and principles:

Chamberlin, T. C., *The Requisite and Qualifying Conditions of Artesian Wells*. Fifth Ann. Rept. U. S. Geol. Survey, 1885, pp. 125–173.

Fuller, M. L., *Summary of the Controlling Factors of Artesian Flows*. U. S. Geol. Survey, Bull. No. 319, 1908, 42 pp.

lowing their more porous layers, and as rapidly as their porosity permitted would be drained away. Under the conditions that exist, however, the mass of the Coastal Plain materials remains constantly saturated with relatively motionless water to within a relatively short distance of the surface, the exact distance depending upon local conditions. The upper limit of the saturated portion is known as the water table.

In the geologic section to which reference was made above it will be observed that a great mass of materials underlying the region adjacent to the coast are of marine origin. When these were deposited they must have been saturated with sea water to the extent permitted by their porosity. It is believed that these beds have never been above sea level, and that the salty waters originally imprisoned in them have never had opportunity to escape from their confinement. An attempted representation of the manner in which this imprisonment has been effected is given graphically in Fig. 17, p. 344. Either the pressure of the sea water, whose specific gravity is greater than that of fresh water (1.027), upon the submerged beds of the Coastal Plain, or the impervious character of the strata, or both together, assisted by the retarding effect of friction, have been sufficient to overcome the hydrostatic pressure from the landward direction. In places at least it is believed that not only has the pressure of the ocean water been sufficient to prevent movement in the direction of the ocean, but that it has actually forced the salty sea water backward into materials which have originated in less brackish or nonbrackish water. The dotted portion of the line in the geologic section, which indicates the upper limit of the salty, noncirculating waters, has been drawn hypothetically, for the reason that no well data are obtainable which indicate its exact position in this portion of the Coastal Plain. The lack of this information is due to the fortunate circumstance that where the data are wanting an abundant supply of good water can be obtained in almost all cases at shallower depths than the postulated upper limit of salty waters.

This great body of noncirculating, salty water serves as an effectual barrier to the passage downward along the inclined beds beyond the limit indicated (see Fig. 17, p. 344) of the waters entering them from the surface. It is believed that above this limit the waters, having been prevented from passing farther down the beds, are able, on account of the pressure from the accumulated mass of water behind them, to pass very slowly oceanward in an approximately horizontal direction through not only the porous sand beds, but likewise the less pervious, compact sand and clay beds, and to enter and mingle with the ocean

FIG. 17.—Section explaining the conditions governing circulation and noncirculation of waters in deposits of the Coastal Plain.

waters. This horizontal movement is so slow that it is scarcely measurable unless the observations, if it be possible to make them, be carried on for long periods of time. But, obviously, the movement is sufficient to prevent the waters from becoming excessively charged with dissolved mineral matter, except locally. The principal evidence of this lateral movement is furnished by the fact that the waters remain relatively fresh. There must be a circulation of some kind in order to enable the waters to retain their fresh character, for were they in a static condition mineral matter would be dissolved from the materials with which they would be constantly in contact, and they would soon become charged to their maximum limit with the products of solution. The explanation offered to account for this circulation seems to be the most probable one. As regards its effect upon hydrostatic pressure in wells, the lateral oceanward movement is so small as to be negligible. From a practical standpoint the water may be regarded as a stationary mass under constant hydrostatic pressure, the pressure being due to the fact that a portion of the mass is at higher levels, and is prevented from seeking its level by various confining agents.

Although the mass of water contained within the sediments of the Coastal Plain is, as a whole, under constant hydrostatic pressure, only the more pervious beds will yield their burden of water with sufficient ease to render them of economic use. The less pervious beds serve as confining agents, and localize the hydrostatic pressure along certain lines. Several of the ways in which pressure is thus localized are shown in Fig. 18, p. 346. Letter *c* indicates a porous sand layer between two relatively impervious clay layers in which the downward passage of the water is prevented by the heavier stationary salty water which fills the lower end of the stratum to the level of *b*; letter *d* indicates communicating sand lenses within a body of materials consisting mainly of less pervious, thinly laminated clay and sand layers, in which the downward percolating waters are obstructed by the heavy salty waters filling the mass below; letter *e* indicates a porous sand stratum pinching out between two relatively impervious clay layers which obstruct downward movement; letter *f* indicates a layer of porous sand changing to compact, impervious sand or clay, producing the same result as the preceding; letter *g* indicates a porous sand layer in which the water is cut off in its downward passage by an unconformity and is confined above by a layer of clay; the letter *a* indicates the surficial covering of Pleistocene deposits.

When one of these porous water-bearing beds is penetrated by a well boring, the water immediately rises within the well opening to some height above the bed itself, the amount of rise depending upon the

strength of the hydrostatic pressure in the given case. If the well opening is at a lower level than the upper limit to which this pressure can lift the water, a flowing well results. In the North Carolina Coastal Plain this upper limit, as a rule, lies below the general upland level in any given region, so that on this upper level flowing wells are

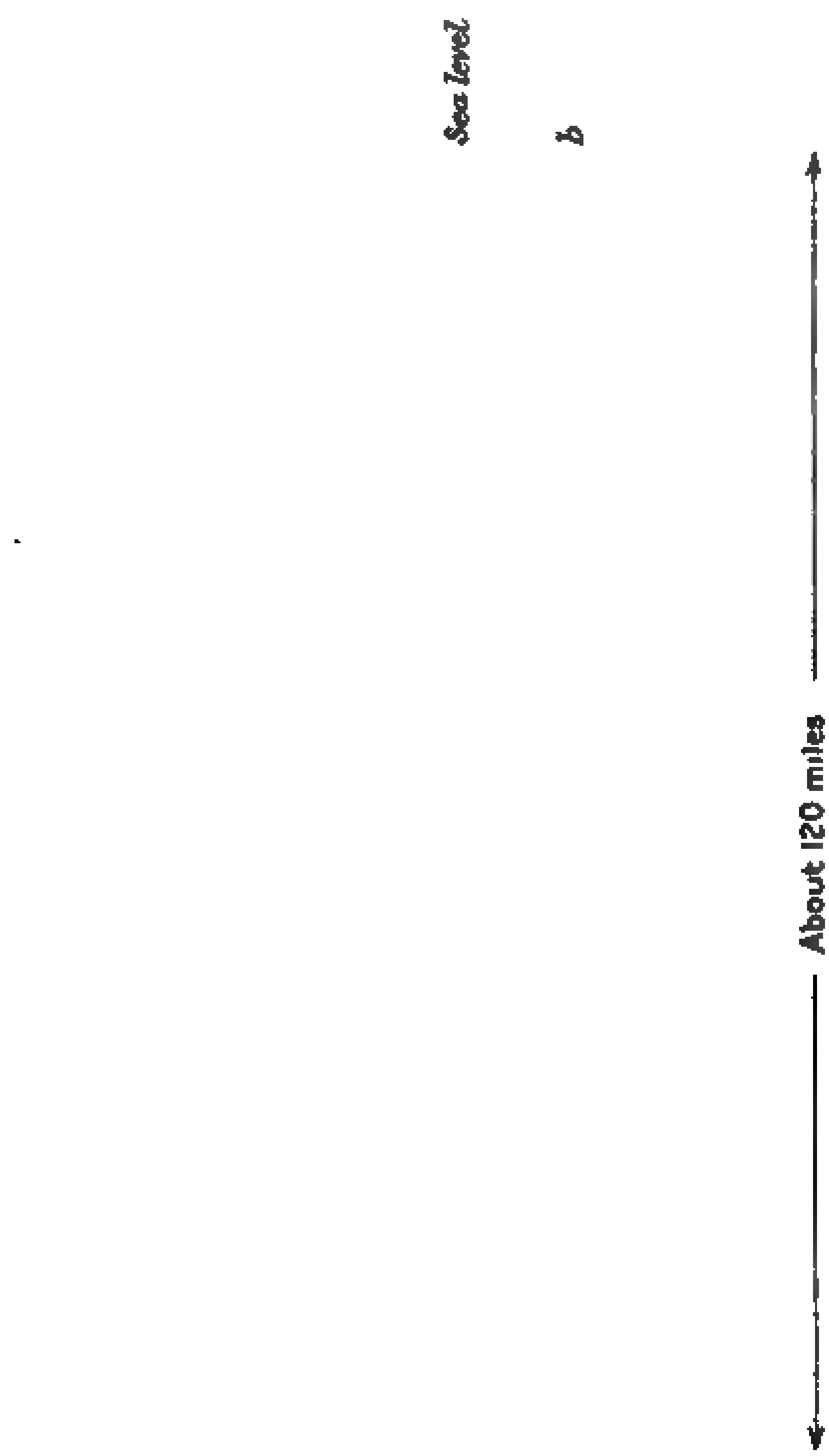


FIG. 18.—Section explaining the efficient causes of artesian flows.

impossible. It is a matter of common knowledge among the inhabitants that flows are more apt to be obtained when the well is located on ground lower than the general level of the immediately surrounding country; that is, in valleys or on low terraces.

A factor not mentioned above which may in certain cases be of importance in determining the height to which water will rise in a well

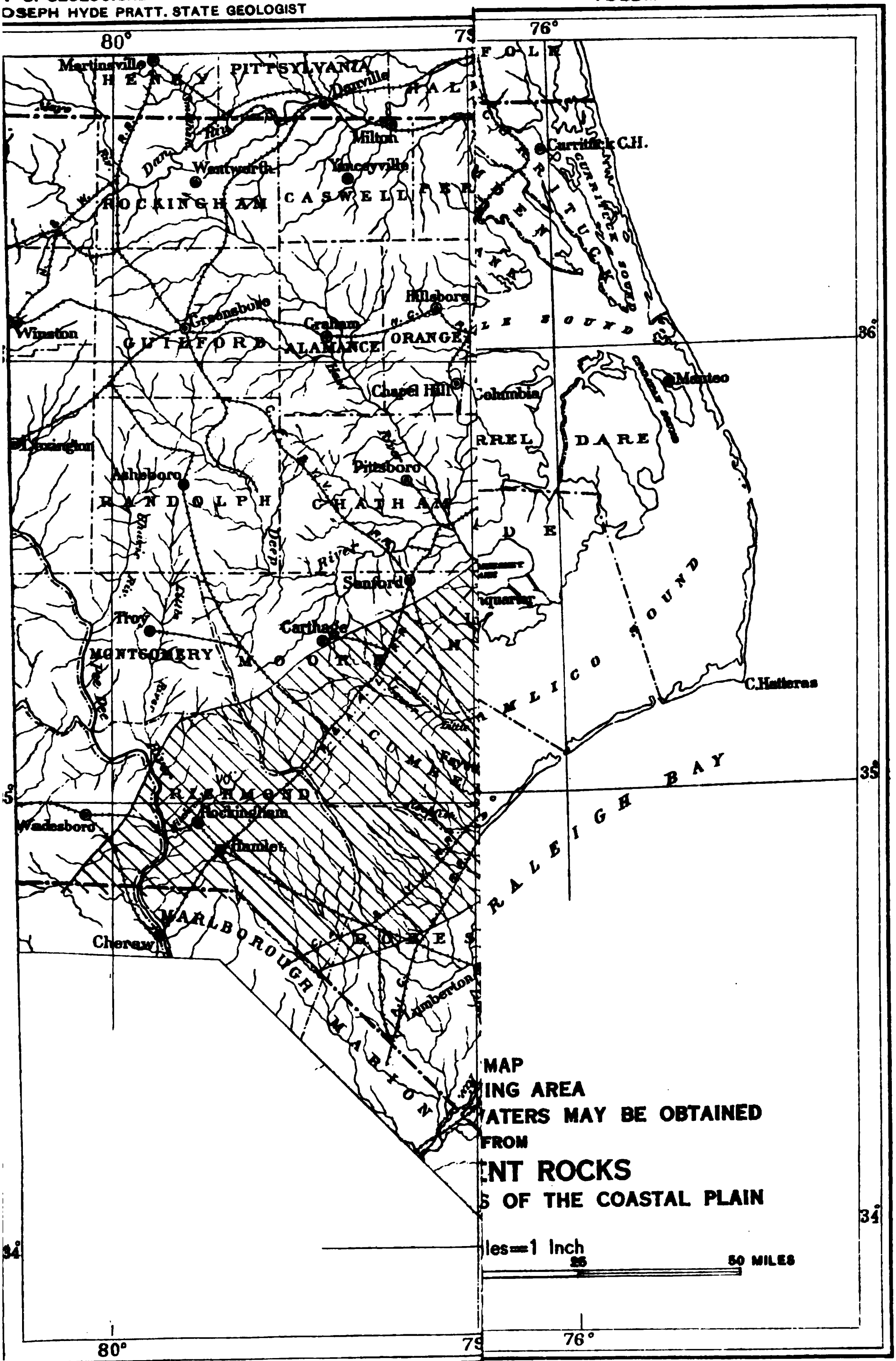
is friction. Water under hydrostatic pressure entering the base of a fine, close sand bed will be hindered by friction from rising as high as it would were it not thus restrained. When a pipe is sunk to the base of the bed this friction is removed and the water rises within the pipe to a higher level than it does in the sand outside the pipe. This difference may in some cases be sufficient to produce flows at the surface.

Another set of conditions producing effective hydrostatic pressure are those shown in Fig. 19, p. 348. The figure represents a cross section taken at right angles to a typical Coastal Plain valley. In the higher lands shown at either end of the section the water table stands higher than in the lower terraces bordering the stream in the center. The relatively impervious stratum *a*, which serves as the confining agent for the water-bearing stratum *b*, permits but little water to pass downward through it; but the pressure resulting from the weight of the mass of water above *a* is transmitted downward through it, producing hydrostatic pressure in *b*. Wells located on the terraces, if sunk deep enough to penetrate *b*, will flow. It is believed that many flowing wells in the Coastal Plain are produced by conditions similar to these.

Other factors than those described, such as temperature and barometric pressure, exert a certain amount of influence upon hydrostatic pressure, but these are believed to be of minor importance, since they operate merely to increase or decrease slightly the effectiveness of that pressure. They are therefore omitted from this discussion.

The upper limit of the saturated portion of the materials making up a land body has been referred to as the water table. This lies at a greater or lesser distance below the surface, depending upon a variety of conditions, such as amount of rainfall, porosity of the materials, configuration of the surface, etc. In the case of swamps it coincides with the surface. It is not a level plain, but conforms in its curves to the curves of the surface, though the degree of curvature is less. In the higher lands it lies somewhat deeper below the surface than it does in the lower lands. Neither does it occupy a fixed position, but fluctuates in response to changes in the amount of rainfall. During periods of excessive rainfall the water table rises; during periods of drouth it subsides. Its subsidence is due in part to the passage of the water downward into the underlying beds, whence it moves slowly oceanward as shown in Fig. 17, p. 344; but in much greater part the subsidence is due to gravitational movement of the water laterally towards the surrounding valley and scarp slopes, where it escapes once more to the surface in the form of springs, and eventually finds its way to the ocean as surface streams.

FIG. 19.—Section explaining the cause of flows in certain wells.



MAP SHOWING AREA IN WHICH P S OF THE COASTAL PLAIN.

GEOLOGIC OCCURRENCE AND CHARACTER OF THE UNDERGROUND WATERS.

BASEMENT ROCKS.

The rocks which form the basement on which the deposits of the Coastal Plain rest consist in the main of ancient crystallines and metamorphics of early Paleozoic or Proterozoic age. They are the eastward continuation of rocks of similar kind which form the greater part of the surface throughout the Piedmont Plateau province. Along the northwestern edge of the Coastal Plain the upper surface of these rocks is very uneven, but in general it dips to the southeast and passes gradually deeper and deeper until along the immediate coast it lies at depths of 1,200 to perhaps 2,500 feet beneath the present surface. It is only along the northwestern border of the Coastal Plain province in a belt some 25 or 30 miles in width, where their buried surface lies at less than 300 or 350 feet below the present surface, that these basement rocks form an important source of water supply. (See map, Plate XXXI.) The artesian conditions which they present, except as slightly modified by the overlying sedimentary beds, are identical with those presented by the rocks of the Piedmont province proper farther to the west. Their treatment here may perhaps be regarded as inappropriate, but since they lie within the area under consideration, a brief statement of their importance as water bearers may not be out of order.

In the belt indicated a large number of wells have been drilled through the overlying deposits of the Coastal Plain into these basement rocks. Many of them furnish an abundance of good water sufficient for use as municipal supplies and for steaming purposes in boilers. Others yield smaller amounts sufficient for the domestic use of one or more families; while some have been failures. From the nature of the rocks it is in most places impossible to predict the outcome of attempts to obtain water from this source. In the case of crystalline rocks which show neither bedding planes nor schistosity the underground circulation depends upon the presence of fissures and the connection of these channels either with the surface or with other water-bearing formations, and obviously the striking of such fissures is more or less a matter of chance. In the case of metamorphosed sediments in which the bedding planes have not been obliterated, or in the case of rocks possessing well-developed schistosity, a regular system of water horizons may exist. If the structure of these rocks can be made out it becomes possible to predict with some confidence where such horizons will be encountered. But in a region such as the one

under consideration, where the rocks are concealed for the most part by superimposed sedimentaries, the detailed study of structure is in most places impossible.

The results of experiments in this area in the past ten or fifteen years have shown that the prospects for getting a supply of water of potable character from this source are good, although there is in the case of every attempt the possibility of failure. Where supplies from other sources are not available, this possible source should not be left untested.

By referring to the separate accounts of the water conditions in the several counties within the belt, detailed information may be had regarding individual wells which obtain their supply from this source. It will be observed that successful results have been obtained at various places from one end of the belt to the other. The largest number of wells in any given area is in the vicinity of Smithfield and Selma in Johnston County. The reason for this lies in the fact that this area is underlain by a slate or phyllite rock possessing definite cleavage planes along which the water is able to pass, and experience has shown that the drill seldom fails to penetrate a horizon at some depth less than 300 feet which will yield moderate to large amounts of water.

In nearly all cases some artesian pressure is exhibited, but so far as known no wells furnishing sufficient artesian pressure to lift the water above the surface and produce flows, and obtaining their supply from rocks underlying the deposits of the Coastal Plain, have been drilled within the area.

CRETACEOUS.

Patuxent formation.—This formation appears in surface outcrops in a long narrow area running northeast-southwest which extends from Roanoke River to the South Carolina line (see geologic map, Plate XVII, in pocket). It rests upon the uneven surface of the underlying basement rocks. The beds dip gently to the southeast and pass unconformably beneath the overlying Black Creek ("Bladen") formation, becoming deeper and deeper in the direction of the coast. Very little is known of their coastward extension, but it appears certain that in the region of the Cape Fear Valley at least they do not extend as far as Wilmington, as shown by the fact that both at Wilmington and at Fort Caswell only marine beds of Upper Cretaceous age were encountered down to the underlying bedrock. Here at least they appear to have pinched out beneath the overlying Upper Cretaceous beds and the basement rocks on which they rest. In that part of the belt extending from

the valley of Contentnea Creek northward the Patuxent ("Cape Fear") beds lie beneath superimposed Miocene beds which must first be penetrated when seeking to obtain water from horizons in the former.

The area over which it is believed possible to obtain potable water from the beds of this formation by means of borings is shown on the map, Plate XXXII. It includes not only the belt of outcrop of the formation, but also an additional strip lying to the southeast of this belt, where it is possible to reach the beds by boring through the overlying younger deposits. It is probable that the Patuxent ("Cape Fear") formation extends farther coastward than the limit indicated on the map, but it is believed that beyond this limit the deeply buried waters are highly mineralized and undesirable for ordinary domestic and manufacturing purposes.

The materials of the Patuxent ("Cape Fear") formation consist of layers and lenses of light-gray, arkosic, more or less micaceous sands and light to dark drab, more or less arenaceous clays. Both the sands and clays are in many places very solid and compact and in places the sand layers are indurated to form solid rock. In the case of the sand the compactness seems to be due in the main to a filling between the grains of very fine kaolin or clay particles. However, open porous layers occur, and this is more especially true along the northwestern part of the area where the materials are in close proximity to the basement rocks from which they were derived. The materials here are coarser as a rule, also, than is true of those farther away from the Piedmont border. It is believed, also, that the buried basal portion of the formation where it rests upon the older rocks consists largely of coarse sands and gravels.

The thickness of the formation, so far as known, appears to be about 300 feet. It may become somewhat thicker, however, for a short distance to the southeast of its belt of outcrop.

Experience has shown that water-bearing beds occur within this formation. The water, of course, circulates more freely in the more porous beds. These may occur at any vertical position within the formation. Owing to the irregularly varying porosity of the different beds it is impossible to predict from surface indications at any given locality at what depth those will be encountered which are sufficiently porous to admit of free circulation of water; but since the beds nearer the base are believed to be in general more porous than those occupying a higher position, it would seem that these would offer the more promising horizons; and in places at least, which can only be determined by drilling, they should furnish very large supplies. The depths at which potable waters should be found in this formation will vary all the way

from 40 or 50 feet along the northwestern border of the belt, where the thickness is limited by the basement rocks which lie at comparatively shallow depths, to 400 or 500 feet in the southeastern border. It seems probable that at most places where the thickness of the formation amounts to 50 feet or more there will be at some depth between its top and base a sand or gravel bed sufficiently porous to furnish supplies for domestic purposes, and at most places sufficient supplies should be found for boiler, manufacturing, and municipal purposes.

Failures to obtain supplies have been reported, the most notable instances being those at Fayetteville. In several wells over 200 feet of Patuxent ("Cape Fear") beds were penetrated and underlying basement slates entered, but only insignificant supplies were encountered. The failures may have been due to one of two causes: first, the beds here may be locally too compact to permit of sufficiently active circulation of waters; or, second, the drillers may have sunk the casing too rapidly, thus passing by good water horizons without detecting them. Should the latter be the true cause of failure, it remains only for some careful and thoroughly competent driller to apply himself to the undertaking in order that these waters be made available for use. Locally, flowing wells have been obtained, as a rule located in valleys below the general level of the surrounding region. Elsewhere, force and suction pumps are employed to bring the water to the surface.

In general, within the limits indicated the Patuxent ("Cape Fear") waters are potable. Those from the region nearest the Piedmont are usually very soft and low in mineral content. Coastward they become somewhat more highly charged with mineral matter, although, as a rule, not excessively so. Locally, the content of iron is high, as at Red Springs in Robeson County, and in many places sodium bicarbonate is present in greater or lesser amount.

The water conditions in the separate counties within this area are treated in detail elsewhere in this report.

Black Creek formation.—The area of surface outcrop of this formation extends with increasing width from Tar River in Pitt County, where it is only a few miles wide, to the South Carolina line, where its width is 30 or more miles. (See geologic map, Plate XVII, in pocket.) The formation rests unconformably upon the eroded surface of the Patuxent ("Cape Fear") formation. The beds have in general a gentle dip to the southeast. They pass conformably beneath the marine beds of the Peedee ("Burches Ferry") formation, reaching greater and greater depths in the direction of the coast. The depth of the upper surface of the formation beneath the surface has been determined

approximately at two places near the coast, the first at Wilmington, where it was encountered at 720 feet, and at Fort Caswell, where it was reached at 1,140 feet.

The area over which potable waters may be obtained from horizons in the formation includes, in addition to the area of outcrop, a strip lying to the southeast of this belt, where the beds may be reached by drilling through the overlying Peedee ("Burches Ferry") and younger beds. (See map, Plate XXXIII.) It is not probable that potable waters can be found in the formation after it passes to greater depths than 400 feet beneath the surface, for at such depths highly saline waters are apt to be encountered.

The materials of the formation are variable in their character, both horizontally and vertically. For the most part, they consist of fine, laminated, micaceous sands and clays, nearly everywhere lignitic and pyritiferous. Wherever extensive outcrops occur it is observed that thick lenses of medium to fine, but as a rule loose sands, are present in some part of the exposure, and this feature is worthy of especial note as regards the importance of the formation as a water bearer, for it is these sand phases which serve as the principal reservoirs and channels for the circulating waters. Marine greensand and calcareous layers become interstratified with the shallower water phases in the upper part of the formation. The thickness of the formation reaches several hundred feet, perhaps 500 or 600, in the region of the Cape Fear Valley, but becomes thinner towards the northeast. It is important as a source of artesian supply throughout that portion of both its horizontal and vertical extent, which does not pass below the upper limit of the deeper, noncirculating salty waters, which, it is believed, will be reached at most places at depths of from 350 to 450 feet. The securing of a good supply of water, however, will depend upon whether or not the drill happens to penetrate a sand lens or layer which is of sufficient extent or which has connection with other sufficiently large similar lenses or layers to permit of a free circulation of the waters; and the amount of the supply will depend upon the freedom of this circulation—that is, upon the number and upon the communications existing between these porous sand phases. Experience has shown that inexhaustible supplies may be tapped at many places.

Along the northwestern part of the belt where this formation overlaps upon the Patuxent ("Cape Fear") formation the thickness is of course slight, and the drill may in many cases pass through the Black Creek formation without encountering a water horizon, and enter the underlying Patuxent ("Cape Fear") formation. As the beds thicken to the southeast, however, the chance for obtaining supplies increases.

In most cases, where the thickness exceeds 50 feet, water in fair quantity is apt to be encountered, and at depths exceeding 100 feet very large amounts are in many cases obtained.

The height to which the water will rise in the wells varies greatly in the different parts of the area, depending upon a variety of conditions which serve as controlling factors in artesian pressure. As a rule, however, flows are obtained only on ground whose surface is lower than the general level of the surrounding region.

With occasional exceptions, the quality of the water obtained from the Black Creek ("Bladen") formation is at least fairly potable, and much of it is excellent. Iron and sulphur in various combinations are the two most abundant mineral constituents in the waters. In places iron is present in excessive amounts, rendering the water unpalatable. The presence of these two constituents is not surprising when it is remembered that iron sulphide in the form of pyrite or marcasite, or both, is almost universally present throughout the beds of the formation. In the upper part of the formation marine calcareous beds are in places intercalated between the laminated portions, and wells drawing on waters which come in contact with these calcareous layers will be high in lime, and therefore hard.

Peedee sand.—Beds of the Peedee formation outcrop in a belt extending from Greenville in Pitt County southwestward to the South Carolina line. At the former place the width is probably less than a mile, but it gradually widens to the southwest, amounting to about 40 miles at its southern extremity. (See geologic map, Plate XVII, in pocket.) The formation rests conformably upon the underlying Black Creek formation. The beds dip gently to the southeast and along most of the southeastern border of the belt of outcrop pass unconformably beneath overlying Eocene limestones.

The materials are almost entirely of marine origin. They consist of grayish or greenish-gray sands, as a rule more or less micaceous and glauconitic, and dark marine clays. The sand layers are in places indurated, the cement being either calcium or silica. Fossil shells are common throughout the beds, rendering them as a rule more or less calcareous. The importance of the formation as an aquifer would not be suspected from the nature of the materials as they appear in most of the surface exposures, for they are as a rule of close, compact texture, apparently unfavorable for water circulation. But well borings at many places have shown that loose-textured, porous sand layers are present, and in fact some of the most important water horizons in the Coastal Plain are furnished by this formation.

The area over which potable waters in the beds of the formation may be reached by borings is shown on the map, Plate XXXIV. It includes not only the area of outcrop, but also an additional strip to the southeast several miles in width, where the beds may be reached by drilling through the overlying beds of Eocene limestone.

The Peedee sand has a thickness at Wilmington of at least 720 feet, and at Fort Caswell of not less than 886 feet, as shown by deep borings. It is probable that a comparable thickness exists at other places along the coast, although over much of the eastern and northeastern part of the State the terrane is deeply buried beneath superimposed Tertiary beds. Water-bearing horizons exist at intervals throughout the vertical extent of the formation; but, unfortunately, at depths exceeding 250 to 400 feet, according to location, the waters from these horizons are so highly charged with sodium chloride (common salt) and other salts, at least so far as tests have been made, as to render them utterly unfit for use. But, on the other hand, fortunately, at most places within the area horizons of potable water exist above those which are excessively saline. A very large number of wells have been drilled to these horizons, especially in Columbus and New Hanover counties, and also in Brunswick, Pender, Duplin, Lenoir, and other counties. Flows have been obtained at many places. Where flows do not occur the water as a rule rises near enough to the surface to be within the reach of ordinary hand force or suction pumps.

In general, the waters from above the lower limits mentioned are of a very satisfactory quality. As a rule, they are somewhat mineralized, but only locally is the mineral content excessive. Calcium and iron are the principal minerals present, and in a few places one or both of these are present in such large amount as to render the waters unpalatable.

For detailed information regarding the artesian conditions in various parts of the area under consideration, the reader is referred to the separate county discussions published elsewhere in this report.

TERTIARY.

EOCENE.

Trent formation.—The extent of the area in which the strata referable to this formation appear in surface outcrops has been determined only approximately. It includes portions of Craven, Jones, and Onslow counties, with a few isolated areas in the counties to the westward between Neuse and Cape Fear rivers, which are unimportant as water bearers. (See geologic map, Plate XVII, in pocket.)

The materials of the formation consist of calcareous marls, fossiliferous limestones, and fine-grained, siliceous sandstones. The maximum thickness of the formation is thought to be about 140 or 150 feet. The formation rests unconformably upon Upper Cretaceous strata belonging to the Peedee formation. The strata dip slightly to the southeast. To the southward the formation is believed to pass unconformably beneath the Castle Hayne formation of the Eocene, and is believed to have been encountered in well borings in New Hanover County. To the northeast it passes unconformably beneath Miocene strata. Over much of the area the formation is covered by thin, surficial Pleistocene deposits.

Inexhaustible supplies are available from the porous, sandy strata intercalated within the limestones, and probably also to some extent from solution channels and caverns within the limestones themselves. These horizons have been tapped at Jacksonville in Onslow County, at Trenton in Jones County, at New Bern in Craven County, at Washington in Beaufort County, and to a limited extent at intermediate points.

In quality the Trent waters are, with very few exceptions, hard to a greater or lesser degree, due to the presence of calcium carbonate in solution. In places the hardness is not excessive. Elsewhere it becomes so excessive as to render the waters unpalatable, and unfit for laundry, boiler, and manufacturing purposes unless subjected to special chemical treatment. Iron salts are present in many of the waters and in some cases the amount is excessive. Unfortunately, over much of this area, including parts where some of the larger towns are situated, as at Jacksonville, Trenton, New Bern, and Washington, no other source of potable artesian waters is available, for by deeper drilling horizons of water high in sodium chloride (common salt) would in all probability be encountered. It remains, therefore, for the people to make the best use possible of this water, which though rendered objectionable in places by its lime content, is nevertheless obtainable in unlimited quantities. It is possible and practicable by proper chemical treatment to remove a large percentage of the calcium and iron salts, and thus to render the water much more satisfactory than in its natural state. Under the head of the separate counties the detailed water conditions of local areas have been discussed elsewhere in this report.

The area in which potable waters may be obtained from Eocene strata, including both the Trent and the younger Castle Hayne formation, is shown on the map (Plate XXXV).

Castle Hayne formation.—Limited outcrops of this formation occur in southeastern Pender, New Hanover, and eastern Brunswick counties, with possibly a few isolated areas to the westward which are unimportant as water bearers. (See geological map, Plate XVII, in pocket at back of Pt. I.)

The materials of the Castle Hayne formation consist of calcareous marls and fossiliferous limestones, with intercalated porous sand layers. Where exposed, the base consists of a phosphatic conglomerate several feet in thickness. The probable maximum thickness of the formation is given as 50 feet.

The formation in its area of outcrop rests with a marked unconformity upon the Peedee formation of the Upper Cretaceous; but coastward it is thought that the Trent formation of the Eocene is intercalated between the Peedee and Castle Hayne formations. The formation is overlain unconformably by thin remnants of Miocene beds and by surficial Pleistocene deposits. The Castle Hayne strata dip slightly to the southeast.

The porous sandy strata intercalated within the harder limestone beds in places furnish large supplies of potable water. It is probable, also, that solution channels in the limestone furnish reservoirs of some importance. These horizons have been utilized in the eastern part of New Hanover County.

Owing to the calcareous nature of the containing beds, the waters from this source all carry greater or lesser amounts of calcium carbonate in solution and are consequently hard. The degree of hardness varies, being as a rule not excessive. In some places, however, the hardness is sufficient to render the water undesirable for laundry and boiler purposes.

On account of the lithologic similarity of this formation to the older Eocene formation, the Trent, and also on account of the fact that the two formations have not been differentiated with any degree of accuracy either geographically or stratigraphically, and also from the further consideration that the quality of the water furnished by each is practically the same, it has seemed best to indicate on the map the area over which potable waters may be obtained from Eocene strata including both of the formations in question. The map shows not only the area of outcrop of Eocene strata, but the additional area to the east and north in which potable waters may be obtained from this source by drilling through superimposed Miocene or Pliocene beds. (Plate XXXV.)

A detailed account of water conditions in New Hanover County will be found on pp. 436-445 of this report.

MIOCENE AND MARINE PLIOCENE.

The Miocene deposits of North Carolina have been divided into three formations, the St. Marys, Yorktown, and Duplin, and the marine Pliocene deposits are included under the Waccamaw formation. The geographic distribution of these terranes may be seen by referring to the geologic map (Plate XVII, in pocket). The St. Marys and Yorktown formations are the most important of these four divisions from the standpoint of water supplies. The Duplin and Waccamaw formations are present merely as thin sheets and remnants over older formations, and are of slight importance. It is believed that strata of Pliocene age, possibly synchronous with the Waccamaw formation, are present beneath the surface and stratigraphically above the Yorktown formation of the Miocene in the low eastern counties of the State, but information concerning their presence is very meager. The formations in question are nearly everywhere overlain by thin, surficial Pleistocene deposits.

Both the Miocene and Pliocene strata consist of alternating layers of drab clays, light gray or greenish-gray sands, and beds of shell marl with sand or clay matrices.

On account of the lithologic similarity of the materials of these several formations, and their occurrence in sequence one upon the other in the northeastern part of the State where they are important as water bearers, it will perhaps be less confusing if the whole series be considered as one unit as regards their availability as a source of water supply.

In this northeastern region the beds dip gently to the eastward, the successively younger strata having their upper edges close to the surface successively nearer to the coast. Along the coast the combined thickness of the beds is believed to be 500 to 800 feet. Westward the series as a whole becomes thinner and finally feathers out at the western limits of their overlap upon older formations.

The more porous, sandy layers in this series of deposits carry very abundant supplies of water which may occur at any vertical position between the base and top of the deposits. Failures to obtain supplies have been reported in places. These may be due to the local predominance of impervious clay layers, but are probably more often due to a too rapid sinking of the casing, which prevents recognition of the possible useful horizons.

Owing to the presence of shells in great abundance almost everywhere in the beds the waters obtained in almost all cases contain calcium carbonate in greater or lesser amounts. In many places the content of this mineral matter is not excessive and the waters are of fair

quality and suitable for most ordinary purposes. Elsewhere the amount is excessive and the waters are unpalatable and not satisfactory for either domestic or manufacturing purposes. Iron salts are present in many cases and, in the case of some wells, in excessive amounts. The odor of hydrogen sulphide may be detected in many of the waters when they first issue from the wells. Flowing wells have been obtained at many places, as a rule, on ground lower than the general level of the region immediately surrounding the wells.

The water conditions of the several counties in the area under consideration have been treated separately elsewhere in this report.

The area over which potable waters may be obtained from the Miocene and marine Pliocene formations by drilling is indicated on the map (Plate XXXVI).

TERTIARY AND QUATERNARY.

SURFICIAL PLIOCENE? (LAFAYETTE FORMATION) AND PLEISTOCENE.

The Lafayette and Pleistocene deposits, because of their lithologic similarity and because both exist as surficial coverings upon older formations, may be appropriately treated under one heading. From the standpoint of the actual, practical use to which they have been put in the past, and the use, though constantly diminishing, to which they are still being put, these formations may be regarded as the most important of all the Coastal Plain aquifers in the State. Their availability as a source of supply, however, is so well known, and the means of obtaining the water are so simple and easily applied that there is little need of treating them exhaustively here.

The Lafayette deposits are present as surficial coverings, probably at but few places exceeding 25 or 30 feet in thickness, along the northwestern border of the Coastal Plain province. (See geologic map, Plate XIII, in pocket.) They rest in part upon ancient rocks, and in part upon beds of the Patuxent formation. They occur for the most part at elevations of from 200 to 500 feet and form mantle-like coverings which cap the tops of, and lap down over the slopes of, the pre-Lafayette hills. The sandhill country in the southwestern part of the Coastal Plain region forms a part of this area. The materials consist of sandy loams and sands, as a rule coarse and in places arkosic, and having at their base at many places a bed of coarse gravels and cobbles. Except very locally, they are loose in texture and permit of the free passage of water among their constituent parts. Where the materials on which the Lafayette deposits rest are more compact and less pervious to water than the Lafayette materials themselves, the basal beds of the latter

carry large amounts of very soft and excellent water. As a rule, the inhabitants obtain supplies from this source by means of comparatively shallow, dug, bored, or driven wells, and employ for lifting the water to the surface either buckets or suction or force pumps. Springs occur at many places along the hill slopes where the underlying less pervious beds outcrop at the surface, and, where conveniently located, are utilized.

As stated above, the water furnished by the Lafayette formation is almost universally of excellent quality, except where subject to nearby surface contamination. Where it is possible to guard against such contamination, no more satisfactory water need be desired for the various domestic purposes.

The Pleistocene deposits, which consist of sandy loams, clays as a rule more or less sandy, sands and gravels, form a comparatively thin covering over practically all the remaining Coastal Plain area. (See geologic map, Plate XIII, in pocket.) The thickness, as a rule, amounts to from 10 to 30 feet. In exceptional cases, however, it reaches as much as 40 feet, and in a few places along the coast to as much as 70 feet or more, as shown by borings.

On the basis of the manner of origin the deposits have been differentiated into five formations, namely, in the order of their age, beginning with the oldest, the Coharie, Sunderland, Wicomico, Chowan, and Pamlico formations. The Sunderland and Wicomico formations correspond respectively to the formations of the same name in Virginia and Maryland, and the Chowan and Pamlico formations together correspond to the Talbot formation of those States. The genesis, areal extent, topographic features, lithologic character, etc., of these formations have been treated at some length in Part I of this report. Since the water conditions presented by all of them are similar in most essential respects, it is not necessary to treat them separately. The basal sandy and gravelly portions of these deposits are almost everywhere water-bearing. The water is as a rule very soft. In the flat, poorly drained, swampy tracts which form a large part of the area of the coastward half of the Coastal Plain the water from this source contains much organic matter due to the presence of decaying vegetation on the surface through which it must percolate in its downward passage. Elsewhere the water is, as a rule, of excellent quality, both from a sanitary and mineralogical standpoint, except where subjected to polluting surface influences such as are common in the vicinity of dwellings. The water is obtained by means of dug, driven, or bored wells, located, as a rule, in close proximity to the dwellings which they are intended to supply. Because of the flat character of much of the area in question, and because of the shallowness of the wells, which as a rule range from 10

to 30 feet in depth, it is next to impossible in the great majority of cases to guard with any degree of certainty against the contaminating effects of decaying organic accumulations such as cesspools, discarded food remnants, slops, etc. This fact is becoming more generally recognized among the inhabitants of the region in question, and one finds almost everywhere among those obtaining water from this source a desire to substitute for it supplies from deeper lying horizons.

Springs occur along the river bluffs, the valley slopes, and the scarps separating the several Pleistocene terraces; they derive their supplies from the basal sandy and gravelly portions of the Pleistocene beds. Where not subject to surface pollution or to the effects of decaying vegetation, the spring waters are of satisfactory quality. Where mineral springs occur the waters are, as a rule, derived from outcrops of older, underlying strata. A comparatively small percentage of the springs are utilized, owing to the inconvenience of their location with respect to the location of dwellings.

WATER RESOURCES OF THE COASTAL PLAIN, BY COUNTIES.

BEAUFORT COUNTY.

Topography.—The surface of Beaufort County is made up of parts of three Pleistocene terrace plains. The lowest or Pamlico plain, which scarcely exceeds 20 feet in elevation above the sea, covers about the eastern one-third of the county and extends as a bordering terrace along either side of Pamlico River to and beyond the western county limit. The next higher or Chowan plain covers the greater part of the remainder of the area, with elevations of from 30 to 50 feet. Portions of the surface of both the Pamlico and Chowan terraces consist of broad stretches of swamp land. Very limited areas in the western part of the county form parts of the third or Wicomico terrace plain at elevations of about 60 feet. The several plains described have been but slightly dissected by stream erosion.

Geology.—Little is known of the detailed geology of this county. The western part of the area is underlain by sands, clays, and shell marls of Miocene age, which are believed to dip eastward and pass beneath similar beds of Pleistocene age, or possibly in part of Pliocene age. Pleistocene sands, clays, and marls underlie much of the area to the east. In the western part of the county the Miocene beds are underlain by Eocene limestones belonging to the Trent formation, similar to those at New Bern. These are penetrated in wells at Washington at from 30 to 150 feet below the surface. A surficial covering of Pleistocene terrace deposits belonging to the Wicomico, Chowan, and Pam-

lico formations, and consisting of fine sands, sandy loams, clays, and probably, in places, of shell marls, are spread over the entire surface of the county.

Water Resources.—The quality of water obtained from shallow driven and open wells in Beaufort County depends largely upon the situation of the wells with relation to the present topography. As noted under topography in this chapter, the eastern third of the county is a low plain whose greatest elevation is less than 20 feet above sea level. The shallow wells situated within this area range from 5 to 20 feet in depth. The sandy loams covering the surface grade down into interstratified, bluish sands, and bluish to drab clays, the latter being often referred to by the well owners as "blue mud." Shell beds occur within the Pleistocene deposits of this area and in the underlying Tertiary. The thickness of the surface deposits is slight, and the ordinary dug wells frequently reach the shell beds from which a hard water is obtained. Wells entering the beds of so-called "blue mud" obtain a poor quality of water; the sands interstratified with the "blue mud" or clay are water-bearing. The water level over this entire lower terrace is very near the surface, and in digging these shallow wells care is taken to keep above the objectionable clay beds. The water of this low plain is rather hard and somewhat high in chlorides and is more highly mineralized than the shallow well waters in higher parts of the county. For this reason cisterns are much in use.

The city of Washington, situated on this lower terrace, is said to be underlain almost entirely by sand to a depth of 10 feet or more, the base of which is water-bearing and has been tapped at many places by bored and driven wells. Among dwellings water from such a shallow source is of course subject to contamination.

In the higher central and western parts of the county shallow wells and springs furnish the chief water supply for domestic use. It is as a rule very soft, and where not subject to surface pollution is of good quality.

About 3 miles north of Washington is a spring owned by the Washington Investment Company which has a flow estimated at 24,000 gallons per 24 hours. This water is sold to a limited extent in the city.

All of the deeper wells of the county obtain their water supply from deposits of Tertiary age, either Eocene, Miocene, or Pliocene. The water is as a rule hard. Except in the lowlands bordering Pamlico River and its tributaries, flowing wells have not been obtained. A considerable number of deep wells have been drilled in the county. The table of well statistics given below includes those concerning which

A.—Open well with handpole lift, near mill of D. C. Way Lumber Company, about 3½ miles above Leechville, Pungo River, Beaufort County, N. C.

B.—Flowing well from Miocene strata at mill of the Interstate Cooperage Company, Belhaven, Beaufort County, N. C. (Flows 50 or 60 gallons per minute.)

information has been obtained. The following notes are added concerning wells not included in the list and concerning conditions in certain towns and localities:

The city of Washington is supplied by a water system owned by the Washington Light and Water Company, the supply being derived from 12 drilled wells. The first four were drilled by the Sydnor Pump and Well Company in October and November, 1902. Their depths range from 103 to 146 feet. The wells were tested separately and each was found to yield not less than 100 gallons per minute, and the actual supply available was much greater. The water company subsequently drilled the remaining 8 wells. These range in depth from 100 to 120 feet. In all of the 12 wells the water rises to within 10 feet of the surface. In drilling, sand and bluish clay were encountered to a depth of 40 feet, below which to a depth of 146 feet strata of shell limestone were penetrated. Samples of the rock taken at a depth of 45 feet contained an abundance of Echinoderm spines. The rock is believed to be of Eocene age.

The 12 wells are all included within an area of one-half acre. They are connected and are pumped by a Gould triplex pump, 8½ by 12 inches, run by a 34 horse-power Fairbanks-Morse gas engine. An additional engine and pump of similar design stand ready for use in case of emergency. Ordinarily, about 375 gallons per minute is pumped, but the wells have a capacity of from 500 to 600 gallons. The water is pumped to a 120,000-gallon standpipe elevated 140 feet above the level of the town. This yields a 62-pound pressure when full, but 95 pounds direct pressure can be applied in case of fire. There are about 9 miles of mains, 65 fire hydrants, 375 taps at houses, stores, etc. About one-third of the total population is supplied by this system. Two hundred and fifty thousand gallons are used daily.

About one-third of the inhabitants of Washington receive their supplies from the water company. The remainder use cisterns and driven and drilled wells. The drilled wells range in depth from 32 to 75 feet. In the northern part of the town, in the lowlands near the foot of the escarpment separating the Pamlico and Chowan terrace plains, there are several wells with small flows having depths of from 32 to 45 feet. This water comes from a shell limestone, probably of Eocene age. Nearly all the mills in Washington use the river water for boiler purposes, except in times of drouth, at which times the brackish water from the sound finds its way this far upstream, compelling the use of the city water, which scales the boilers badly.

At Blounts Creek there are 8 or 10 drilled wells 67 to 87 feet in depth, the water rising to within 0-18 feet of the surface. It is reported

that one of these flowed when first drilled and furnished sufficient water to supply two boilers. These wells were all drilled in 1905. The water is hard. (See Table 1, assay 4, pp. 492, 493.)

At Bonnerton, driven wells 10 to 16 feet deep penetrate the marl and yield hard and ferruginous water from the sandy beds in the marl. Mr. W. H. Whitley has a well 100 feet deep located near the mouth of Durham's Creek, which flows a small stream.

At Winsteadville, in driven wells 10 to 40 feet in depth there is found an abundance of water in the marl beds. Within the last few years many 1¼-inch wells have been drilled mainly for supplying stock with drinking-water.

At Leechville, the boilers of the mill are supplied from a well 85 feet in depth and with a diameter of 2½ inches.

At the machine shops of Mr. Surry Parker at Pinetown there is a system of 24 wells ranging in depth from 51 to 71 feet, all coupled to one 6-inch main. The water is pumped by a Gould triplex pump to a tank of 40,000 gallons capacity, the bottom of which is 55 feet above the ground. About 2,000 feet of water mains have been laid, besides about 1,000 feet of smaller pipe. These wells supply a 160 horse-power boiler at the sawmill and two smaller boilers aggregating 50 horse-power at the machine shop, and also supply all the water used for

BEAUFORT

Number.	Location.	Owner.	Date completed.	Elevation of surface above datum—feet.	Datum.	Depth—feet.	Diameter—inches.	Depth to principal water supply—feet.	Height of water ± surface—feet.
1	Washington	Washington Light and Water Co.	1902	10	sea level.	146	8	100	—10
2	....do	....do	1902	10	sea level.	113	6	100	—10
3	....do	....do	1902	10	sea level.	141	6	100	—10
4	....do	....do	1902	10	sea level.	103	8	100	—10
5	....do	Washington Municipal Electric Light and Power Co.	1905	10	sea level.	100+	3	90-100	— 4
6	....do	Washington Investment Co.	1906	10?	sea level.	57	2	57	+ 0
7	....do	J. J. Woolard	1906	10?	sea level.	32	2	32	+ 2
8	....do	R. R. Warren	1905	12	sea level.	75	3	67	—16?
9	....do	H. C. Bragaw				50	2		
10	....do	J. C. Rodman	1905	20	sea level.	80	3		— 5
11	Washington, 2½ miles N. W. of.	W. D. Grimes, Washington		about 10	sea level.	122	1½	100-122	
12	Washington, 9 miles E. of	Marcellus Jordan	1906			140	2	140	—18

domestic purposes in the village, the population of which is about 450. A 240-foot well was drilled here, but as the water could not be obtained as freely as at the depths mentioned above, this deep well was abandoned. Several attempts have been made to secure an overflow at Pinetown, but in no well has the water risen higher than within 10 feet of the surface.

At Belhaven, in addition to the wells listed, there are several others having a depth of about 100 feet.

Assays and analyses of waters from this county are given elsewhere in this report, as follows: Table 1, pp. 492, 493, assays Nos. 1-9; Table 2, analyses Nos. 1-5. These are discussed on pp. 484, 485.

Artesian Prospects.—The sand strata of the Pliocene and Miocene deposits which underlie the greater part of the county, and the porous shell limestones of Eocene age which underlie the western part of the county, carry abundant supplies of water. Owing to the presence of a large amount of lime in these beds the water is apt, in nearly all cases, to be hard. Deeper drilling to depths of 400 or 500 feet would probably encounter horizons yielding salty waters. Flowing wells are possible on the lowlands bordering Pamlico River and its tributary streams at elevations which as a rule will not exceed 10 feet above sea level.

COUNTY.

Yield per Minute.		How obtained at surface.	Use.	Geologic horizon and character of water-beds.	Remarks.
Flow—gallons.	Pump—gallons.				
....	100+	Gould Triplex Pump 8¼x12; 34 h. p. gas engine.	city water supply.	Trent formation; porous limestone or ls. alternating with sand layers.	Other horizons at 10, 40-60 ft.
....	100+		city water supply.	Trent formation; porous limestone or ls. alternating with sand layers.	Other horizons at 10, 40-60 ft.
....	100+		city water supply.	Trent formation; porous limestone or ls. alternating with sand layers.	Other horizons at 10, 40-60 ft.
....	100+		city water supply.	Trent formation; porous limestone or ls. alternating with sand layers.	Other horizons at 10, 40-60 ft.
....	30	....	boiler.	Trent formation; porous limestone or ls. alternating with sand layers.	Located 250 ft. from nearest waterworks well and taps same horizon. See analysis No. 4, table 2, pp. 504, 505.
3+	....	flows.	....	Trent formation; porous limestone or ls. alternating with sand layers.	See water assay No. 8, table 1, pp. 492, 493.
½	....	flows.	....	Trent formation; porous limestone or ls. alternating with sand layers.	See water assay No. 7, table 1, pp. 492, 493.
....	....	....	....	Trent formation; coarse white gravel.	
....	....	....	....	Trent formation.	
....	....	....	....	Trent formation.	
....	....	pitcher pump	domestic.	Trent formation; sand.	
....	....	....	....	Trent formation? sand.	

BEAUFORT

Number.	Location.	Owner.	Date completed.	Elevation of surface above datum.	Datum.	Depth—feet.	Diameter—inches.	Depth to principal water supply—feet.	Height of water, ⊥ surface—feet.
13	Wharton, 2 miles N. of	C. C. Williams	......	10	sea level.	40?	2	....	+
14	Pinetown	Surry Parker	1900	44	sea level.	55	1½	51	—10
15	Chocowinity	N. C. Hughes	......	40	sea level.	140	1½	....	—10
16	Jessama, 1½ miles S. E. of	L. H. Cutler	1906	......	....	95	2	....	— 6
17	Hunters Bridge	John H. Oden	1906	......	....	130	2	125	— 3
18	Blounts Creek, 2½ miles S. W. of.	John R. Norman	1905	......	....	77	2½	77	—18
19	Edward	J. U. Edwards	1905	......	....	105	1½	....	......
20	Aurora	C. L. Dickson	1904	6	sea level.	115	1½	115	— 3
21	....do	J. B. Whitehouse	1902	6	sea level.	184	1½	....	+ 0
22	Aurora, at Bennett's Camp, E. side South Creek, 2 miles S. of Aurora.	Bennett & Leach	1905	5	sea level.	140±	2	135	— 1½
23	Idalia	H. B. Bell	about 1900.	......	....	204½	2	204	+ 0
24	South Creek	Springer Lumber Co.	......	......	....	90	2	....	......
25	Bath, 3 miles E. of	W. D. Edmonson	1906	......	....	140	2	....	— 2
26	Bath	T. A. Brooks	1906	7	sea level.	121	2	....	+ 0
27	....do	Mrs. Lucy Myers	1906	9	sea level.	185?	2	....	+ 8
28	Bath (near)	W. B. Rodman	......	......	....	140	......	....	......
29	Gaylord, ½ mile E. of	W. H. Gaylord, Bath, N. C.	1888	10	sea level.	170	2	170	— 6
30	Yeatesville, 5 miles E. of	Now owned by John L. Roper Lumber Co.	1891	......	....	215	3	....	+ 2½
31	Belhaven, edge of Pantego Creek.	Interstate Cooperage Co.	1906	1	sea level.	300?	3	300	+ 6
32	Belhaven	B. C. Kirk	1903	5±	sea level.	86	2	47	— 6
33	....do	J. B. Clark	1901	5±	sea level.	85	2	....	......
34	....do	Norfolk Southern R. R.	1906	4±	sea level.	60	2?	60	— 2
35	....do	Belhaven Ice Co.	1903	1½	sea level.	96	3	96	0
36	....do	Interstate Cooperage Co.	1905	1±	sea level.	100	2½	....	— 4
37	....do	....do	1905	1±	sea level.	100	2½	....	— 4
38	....do	....do	1905	1±	sea level.	100	2½	....	— 4
39	....do	John L. Roper Lumber Co.	1906	......	....	110	3	....	— 4
40	....do	....do	1906	......	....	120	3	....	—18
41	....do	....do	1906	......	....	80	3	....	—18
42	Leechville, 3 miles N. of	Interstate Cooperage Co.*	1891	6	sea level.	308	3	300-308	+ 2
43	Rover, 3 miles E. of	S. R. Fowle	......	......	....	115	3	....	+ 8
44	Jack's Creek, west side of Pungo Creek.	John L. Roper Lumber Co.	about 1893.	......	....	260?	3	....	......
45	Bunyon	W. S. Eborn	......	......	at low level.	......	¾	....	+ 0

*Formerly owned by D. C. Way Lumber Co.

COUNTY—CONTINUED.

Yield per minute. Flow—gallons.	Yield per minute. Pump—gallons.	How obtained at surface.	Use.	Geologic horizon and character of water-beds.	Remarks.
small.	----------	flows.	domestic.	Miocene.	See water assay No. 9, table 1, pp. 492, 493.
----------	----------	----------	----------	Miocene; coarse white sand.	
----------	----------	hand pump.	domestic.	Trent formation; sand.	
----------	----------	----------	----------	Miocene? varicolored rock.	Another well at Jessama obtained hard sulphurous water at 140 ft.
----------	----------	----------	----------	Miocene.	
----------	----------	----------	----------	Miocene; rock.	
----------	----------	----------	----------	----------	No water obtained.
----------	----------	----------	----------	Miocene?	In the wells at and near Aurora beds of shell marl of Miocene or later age occur at shallow depths. The sand beds interstratified in the marl yield a sulphur water high in iron, which is reported to attack boilers rapidly.
----------	----------	----------	----------	Miocene? black sand.	
13⅜	----------	flows.	domestic.	Miocene?	
2	----------	flows.	----------	Miocene; cavity in rock.	Another horizon at 33 ft. See water assay No. 5, table 1, pp. 492, 493.
----------	abundant supply.	----------	----------	Miocene.	Too hard for boiler use and well abandoned.
----------	----------	----------	----------	Miocene?	
1½	----------	flows.	----------	Miocene? black sand.	Casing became magnetic while drilling, but lost magnetism. See assay No. 2, table 1, pp. 492, 493.
----------	----------	----------	----------	Miocene?	
----------	----------	suction pump.	----------	Miocene.	See U. S. G. S. Bulletin 138, p. 195.
----------	----------	pump.	domestic and boiler.	Miocene; porous rock?	
50 or 60	----------	flows.	----------	Miocene; soft rock.	Strata penetrated, sand with interstratified beds of marl and shell-rock. See U. S. G. S. Bulletin 138, p. 195.
50+	----------	flows.	drinking and manufacturing.	Miocene; gravel.	See analysis No. 1, table 2, pp. 504, 505.
----------	25	----------	----------	Miocene; sand.	Several beds of marl and shell 12-14 inches thick penetrated.
----------	----------	----------	----------	Miocene.	
----------	----------	----------	----------	Miocene.	Scales boilers badly.
----------	abundant supply.	duplex steam pump.	condenser and manufacture of ice.	Miocene? from beneath rock.	Water distilled before used in manufacture of ice. Hard and scales boilers badly. See analysis No. 2, table 2, pp. 504, 505.
together yield 34 gallons.	----------	steam pump.	----------	Miocene?	
	----------	steam pump.	----------	Miocene?	
	----------	steam pump.	----------	Miocene?	
----------	----------	----------	----------	Miocene?	
----------	----------	----------	----------	Miocene?	
----------	----------	----------	----------	Miocene?	
11½	----------	flows.	to limited extent for drinking.	Miocene; from under rock.	Pronounced mineral water by J. A. Holmes. See analysis No. 3, table 2, pp. 504, 505. Other horizons at 80, 100 and 120 ft.
----------	----------	flows.	----------	----------	
----------	----------	strong flow.	----------	Miocene.	Reported to have strongest flow of any well in this section.
----------	----------	flows.	boiler.	Miocene; porous rock.	

BERTIE COUNTY.

Topography.—Topographic maps of the U. S. Geological Survey cover but a small part of the area of Bertie County. Such data as are available indicate that the surface is made up of three Pleistocene terrace plains. The lowest, the Pamlico plain, with elevations not exceeding 25 feet, has a limited development along the north side of Roanoke River and possibly along Cashai River; the next higher, the Chowan plain, with elevations of 30 to 50 or 60 feet, is developed in a belt of undetermined width north of Roanoke River along the entire southern border of the county and also along Cashai River; the third or Wicomico plain, at elevations of 60 to 100 feet, forms the surface over the remainder of the county. These several plains are more or less dissected by stream erosion. Broad stretches of swamp land of recent origin border Roanoke River.

Geology.—Miocene deposits consisting of gray or greenish-gray sands, drab clays, and shell marl, underlie the greater part of the county beneath a thin covering of the sands and sandy loams which make up the Pleistocene terrace formations. The latter are the Wicomico, Chowan, and Pamlico formations. In the extreme western part of the county along Roanoke River the compact, drab or greenish drab clays and gray, arkosic sands of the Patuxent formation (Lower Cretaceous) rise a few feet above water level and probably immediately underlie the Chowan formation, which here borders the river. The Patuxent beds pass beneath the Miocene, becoming deeper to the eastward.

Water Resources.—The basal, sandy portions of the Pleistocene formations furnish the greater part of the supply of water for domestic use. Driven wells are gradually taking the place of open wells, and with the exception of Aulander the villages now contain more of the former than the latter. The wells range in depth from 8 to 35 feet, with a few as deep as 60 feet. Those exceeding 35 feet derive their water from the underlying Miocene. The water from the Pleistocene beds is almost everywhere soft; in places it is ferruginous. Many springs occur along the scarps and in the stream valleys, but they are small and unimportant.

A few deep wells have been drilled in Bertie County. Seven or eight years ago at Windsor a 2½-inch pipe was sunk 250 feet, obtaining a small flow which, after continuing for about three months, suddenly stopped, due to the entrance of sand into the pipe. In 1905 a deep well was drilled for the town near the one above described. The elevation of the mouth of the well above sea level is about 10 feet. A small flow was obtained at a depth of 250 feet and an 8-inch casing

was driven to that depth; drilling was continued, using a 6-inch casing; at 560 feet a flow of approximately 10 gallons per minute was obtained, but was lost either by caving or by casing past the water stratum. Ten feet deeper, at 570 feet, a flow of 4 gallons per minute was struck; this flow was also lost. Drilling was continued to a depth of 585 feet, but no other water-bearing beds were penetrated. An attempt was made to pull up the 6-inch casing, but it parted about 10 feet below the bottom of the 8-inch casing, and only the upper 260 feet was withdrawn. The water from the 250-foot horizon has a strong sulphurous odor and taste. (See Table 2, analysis 6, pp. 504, 505.) The three flows obtained were probably from the Patuxent formation, which underlies the Miocene.

An attempt to get a flowing well was made about three years ago in Lewiston. A 2-inch pipe is reported to have been sunk 164 feet, where drilling was stopped by quicksand. Water, struck at about 100 feet, rose to within a few feet of the surface. This well probably passed through the Miocene and entered the Patuxent formation.

At Avoca a pipe was driven to a depth of 180 feet without securing a flow of water. At this depth quicksand interfered so seriously with the progress of the work that the undertaking was abandoned.

Artesian Prospects.—Abundant supplies of potable water may be obtained from the Miocene and Patuxent deposits underlying the county. It is believed that the depths at which the water-bearing beds will be encountered will vary considerably in the different parts of the county. At Windsor, in the south central part, a flow of water was found at 250 feet. Stronger flows were found at 560 and 570 feet. In the western part of the county the depth to these horizons will be considerably less. Basement rocks would probably be encountered 500 to 600 feet below the surface in the extreme northwestern corner. In the eastern portion of the county water-bearing horizons in the Miocene would probably be penetrated at depths ranging from 35 to 400 or 500 feet below the surface. With the exception of Windsor, none of the larger towns are situated favorably for obtaining flowing wells. It is doubtful if any well drilled within the county will overflow at elevations of more than a few feet above sea level.

BLADEN COUNTY.

Topography.—No topographic maps have been made of any portion of this county. From information obtained from railroad profiles and from field observations it is believed that the surface of the county presents three of the Pleistocene terrace plains recognized in this region. The highest, the Sunderland plain, with elevations of 110 to

150 feet, covers the greater part of the northwestern two-thirds of the county; the next lower, the Wicomico plain, with probable elevations of 60 to 90 feet, covers the southeastern one-third of the county and extends up Cape Fear River as a bordering belt of undetermined width to the county line on the north and beyond into Cumberland County; the Chowan plain, with elevations of 30 to perhaps 50 feet, has a limited development along Cape Fear and Black rivers in the southeastern part of the county. The lowest, or Pamlico plain, is not known to extend this far up the valleys. The several plains described have been more or less dissected by stream erosion.

Geology.—The Black Creek ("Bladen") formation, consisting of laminated, lignitic sands and clays, underlies the northwestern half of the county and, dipping to the southeast, passes conformably beneath the overlying Peedee ("Burches Ferry") formation. The latter consists of marine sands and clays, which are in most places more or less glauconitic and calcareous. Over parts of the county thin sheets of Miocene and Pliocene sands and shell marls rest upon the surface of the Peedee and Black Creek formations. Pleistocene terrace deposits of the Sunderland formation, the Wicomico formation, and the Chowan formation, consisting of sandy clays, sands, and gravels, are spread over the surface of all older formations.

Water Resources.—The greater part of the domestic water supply of this county is furnished by shallow, open, dug wells, and by driven wells ranging in depth from 10 to 30 or 40 feet. The sources of the supply in these wells are for the most part the sand and gravel beds forming the base of the surficial Pleistocene formations. Some, however, pass

BLADEN

Number.	Location.	Owner.	Date completed.	Elevation of surface above datum feet.	Datum.	Depth—feet.	Diameter—inches.	Depth to principal water supply—feet.	Height of water, ± surface—feet.
1	Point Caswell, 3 miles W. of	Frank Sessoms	1896	12	level of Black River.	98	1¼	95	+ 0
2	Bolton, 4 miles N. of	North Carolina Trucking Development Co.				70?	1¼		+ 0
3	Kelly, ½ mile W. of	E. H. Anders				84	1¼	70-84	— 2
4	Emerson					175	2		
5	Clarkton	O. L. Clark	1900	50?	sea level.	150?	1¼		+ 2
6	do.	N. A. Currie & Bro.	1906	104		190±	2	165-185	— 5
7	do.	S. Mears		75?		100±			— 3
8	do.	T. L. Hutchinson				100			

through these and enter the underlying Black Creek, Peedee, Miocene, or Pliocene beds, as the case may be. Springs occur along the valley slopes, and these have been made use of to a limited extent.

In recent years the value of the Black Creek and Peedee formations as sources of good water supplies has come to be more generally recognized and in certain parts of the county numerous deeper wells have been drilled penetrating the water horizons of these formations.

The reader is referred to the table of well data given below for detailed information regarding the deeper wells of the county concerning which information has been obtained.

Assays and one analysis of waters from this county are given elsewhere in this report, as follows: Table 1, pp. 492, 493, assays Nos. 10-22; Table 2, pp. 194, 195, analysis No. 7. These are discussed on p. 485.

Artesian Prospects.—In general, the prospects for obtaining potable artesian water supplies are good in all parts of the county. The depth at which water horizons will be encountered will vary irregularly in different localities, and the only way to determine the depth to these horizons in particular localities, and it might almost be said for particular locations of individual wells, is by drilling. In most places, however, a water-bearing bed or beds will be encountered between the depths of 50 and 300 feet.

Within several miles of the Cape Fear and Black rivers flows are not apt to be obtained except on low ground where the mouth of the well is not more than a few feet above the stream level. In the extreme western part of the county, however, experience has shown that small flows may be obtained as high as 100 feet or more above sea level.

COUNTY.

Yield per minute.		How obtained at surface.	Use.	Geologic horizon and character of water-beds.	Remarks.
Flow—gallons.	Pump—gallons.				
2½	....	flows.	domestic.	Peedee formation; white sand.	See water assay No. 20, table 1, pp. 492, 493.
3-16	....	flows.	domestic.	Peedee formation.	
....	....	hand pump.	domestic.	Peedee formation; greenish sand.	
....	....	....	....	Black Creek formation.	
....	....	flows.	domestic.	Black Creek formation; sand.	
....	....	pump.	domestic.	Black Creek formation; sand.	Another horizon at 50 ft.
....	4	....	domestic.	Black Creek formation; sand.	
....	....	....	....	Black Creek formation.	

BLADEN

Number.	Location.	Owner.	Date completed.	Elevation of surface above datum.	Datum.	Depth—feet.	Diameter—inches.	Depth to principal water supply—feet.	Height of water, ± surface—feet.
9	Clarkton	J. C. Gore				90			
10	Abbottsburg	S. A. L. Johnson				80			
11	...do	J. L. Hall				100			
12	...do	E. E. Craven	1905	75?	sea level.	123	2½	123	—12
13	Bladenboro	R. L. Bridger	1900	about 100.	sea level.	70	----	60	+ 5
14	...do	H. C. Bridger	1892	about 105.	sea level.	60	1¼		+ 2
15	...do	C. H. Williamson	1894	105	sea level.	45	1½	45	+ 0
16	...do	...do	1897	about 100.	sea level.	50	1		+ 0
17	...do	S. N. Ferguson, Red Springs, N. C.	1903	100	sea level.	50	2	44	+ 7½
18	...do	M. C. Edwards	1895	about 105.	sea level.	93	1		+ 0
19	Tarheel	T. J. Purdie, Dunn, N. C.	1900	150?	sea level.	290?	1½	150	—80
20	...do	C. H. Waterson				150			
21	Ellis	E. F. McCulloch				100	1½		

BRUNSWICK COUNTY.

Topography.—The entire surface of the county is formed of Pleistocene terrace plains. No topographic maps have been made of any portion of the area, but it is believed that the Chowan plain at elevations of 30 to 50 feet forms the greater part of the surface. Green Swamp, which has an extensive development in Columbus County, extends into Brunswick County from the north. It is believed to form a part of this plain. The lowest or Pamlico plain is believed to have a very limited development along the coast and along Cape Fear River. The Wicomico plain at elevations of 60 to 70 feet is believed to cover a small area in the extreme north. Shallow valleys have been formed in these plains by stream erosion.

Geology.—Marine sands, clays, and marls of the Peedee formation underlie the entire county. In the eastern part of the county they pass beneath Eocene limestones belonging to the Castle Hayne formation, and in the Quarantine Station and Fort Caswell wells were encountered at depths of 265 and 254 feet respectively. Surface outcrops of the Peedee formation occur along Cape Fear River in the extreme northern part of the county. Throughout the greater part of the county the surface of the Peedee formation is believed to lie at comparatively shallow depths beneath the surficial Pleistocene beds; but in places thin beds of shell marl or sand of Miocene or Pliocene

COUNTY—CONTINUED.

Yield per minute. Flow—gallons.	Yield per minute. Pump—gallons.	How obtained at surface.	Use.	Geologic horizon and character of water-beds.	Remarks.
....	....	....	....	Black Creek formation.	
....	....	....	....	Black Creek formation.	
....	....	....	....	Black Creek formation.	
....	....	pump.	domestic.	Black Creek formation; sand.	Other horizons at 23 and 84 ft.
....	....	pump.	domestic.	Black Creek formation; gravel.	
6	....	flows.	domestic.	Black Creek formation.	
2	....	flows.	domestic.	Black Creek formation; sand.	
2	....	pump.	domestic.	Black Creek formation; sand.	
24	....	flows.	domestic.	Black Creek formation; sand.	Other horizons at 16 and 28 ft.
....	....	pump.	domestic.	Black Creek formation; sand.	
....	....	....	not used.	Black Creek formation; sand.	
....	....	....	....	Black Creek formation; sand.	
....	....	....	....	Black Creek formation; sand.	

age intervene between the Cretaceous and Pleistocene beds, while in the east, in a narrow belt extending from Wilmington to Fort Caswell, the Eocene limestones mentioned above intervene, dipping eastward, becoming thicker toward Cape Fear River, and passing below water level before the river shore is reached. Pleistocene terrace deposits belonging in part to the Wicomico formation, but in greater part to the Chowan formation, consisting of sands, sandy loams and clays, form a surficial covering over nearly all the county. In the east along Cape Fear River estuary where the waves are cutting into the Chowan terrace the thickness of the Pleistocene deposits amounts to at least 30 feet, the entire face of the bluffs down to water level presenting beds of this age. Along the coast and along Cape Fear River there is a very limited development of beds belonging to the Pamlico formation.

Water Resources.—Shallow, open, and driven wells, ranging in depth from 10 to 25 feet, which derive their supply from the base of the surficial Pleistocene formations are common throughout the county. Springs, which are used to a limited extent for domestic purposes, are present in many parts of the county, occurring along the valley slopes. Deep wells have been drilled at a number of places in the county. In the table of well data given below are included those concerning which detailed information has been obtained.

A few additional notes may be added concerning wells and water conditions in the county.

At Fort Caswell, situated on Oak Island near the mouth of Cape Fear River, several unsuccessful attempts have been made, under Government auspices, to obtain potable water by deep boring. The first well was drilled between the years 1900 and 1902. The depth was 800 feet and the smallest casing used was 6 inches in diameter. No potable water was obtained. A brackish water horizon was encountered in Cretaceous beds at a depth of 365 feet, and in the lower 80 feet of the well water of similar quality was struck which flowed at the surface at the rate of about 2 gallons per minute. Assay 23, Table 2, is a test of the water of this well. In 1903 a 6-inch well was sunk to a depth of 171 feet without obtaining satisfactory water. The last and most determined attempt was made between the years 1905 and 1907. A well was sunk to a depth of 1,543 feet, the smallest casing being 7 inches in diameter. (See section, p. 169.) The deposits of the Coastal Plain were completely penetrated, basement rock being entered at about 1,540 feet below the surface. No potable water was encountered, the content of sodium chloride (common salt) being excessively high in all the horizons penetrated. A strong flow of salty water was encountered in Cretaceous beds at a depth of 1,442 feet.

The water now used at Fort Caswell is obtained from shallow wells 15 to 30 feet in depth, and from cisterns. The well water is brackish, due to the infiltration of sea water through the porous beach sands which make up the underground materials for some distance below the surface at this place.

At the Quarantine Station which is located in the middle of Cape Fear River on piles about one mile east of Southport, a well was drilled to a depth of 400 feet below sea level. The diameter of the smallest casing used was 4½ inches. At the bottom of the well a horizon of potable water was encountered in the Peedee formation, which yields by pumping at the rate of 75 gallons per minute. A peculiarity of this well is that when first pumped after standing idle for several hours the water is brackish, but after about 20 minutes pumping the taste of salt entirely disappears, and as long as the well is pumped continuously the quality of the water is satisfactory. (See Water Supply and Irrigation Paper, U. S. Geol. Surv., No. 160, 1906, p. 97.) Analyses 10 to 23, Table 2, are tests of this well. (See section, p. 168.)

Three wells have been drilled at the plant of the American Fisheries Company on Cape Fear River, near Old Brunswick. The depth of each is 140 feet and the diameter is 3 inches. One yields by pumping at the rate of 50 gallons per minute and the other two at the rate of 100 gallons each per minute. This water horizon is probably in the Eocene.

At Elpaso the wells range to a depth of 40 feet, and in the deeper wells the water is probably derived from the Eocene.

At Malmo water is obtained from nonflowing wells at various depths down to 54 feet. In those exceeding 25 feet the water probably comes from the Peedee sand.

In the western part of the county a well is reported at Excelsior 160 feet in depth, one at Ash 200 feet, and one at Iredell 280 feet. These all penetrate Peedee horizons.

Assays and analyses of waters from this county are given elsewhere in this report, as follows: Table 1, pp. 492, 493, assays Nos. 23-28; Table 2, analyses Nos. 8-23, pp. 504, 505. These are discussed on p. 485.

Artesian Prospects.—Throughout the greater part of the county water for domestic purposes may be obtained by drilling to depths not exceeding 300 to 400 feet. Over most of the county wells exceeding 30 or 40 feet in depth will penetrate the Peedee beds. In the southeast, however, where these beds pass under the Eocene the depth at which they will be reached increases, and in the extreme southeast it will amount to from 200 to 250 feet.

The deepest horizon yet discovered yielding a potable water is that penetrated in the Quarantine Station well at a depth of 400 feet. As regards the quality of waters from depths exceeding 400 feet, a sufficient number of tests have not been made to justify a sweeping statement; but from such as have been made it seems probable that from horizons exceeding this depth all waters will be too salty to be of use for domestic or manufacturing purposes. At Fort Caswell several attempts have been made to obtain potable water (see table, pp. 66, 67), but without success. The briny water of the present sea penetrates the loose sands to a depth of at least 30 feet and possibly to the base of the Pleistocene at 78 feet. (See section, p. 168.) Below the depth indicated there seems to be no strong flow of water until the salty waters of the Peedee sand are reached, the first of which was encountered at a depth of 365 feet. All horizons below this depth to bedrock at 1,540 feet furnish a highly saline water.

BRUNSWICK

Number.	Location.	Owner.	Date completed.	Elevation of surface above datum—feet.	Datum.	Depth—feet.	Diameter—inches.	Depth to principal water supply—feet.	Height of water, ± surface—feet.
1	Fort Caswell	U. S. Government	1900	10?	sea level.	800	6	719	+ 0
2	do.	do.	1903	10?	sea level.	171	6	......	......
3	do.	do.	......	10?	sea level.	1,543	....	strong flow at 1,442.	......
4	Southport	Town	1902	20?	sea level.	103	2	101	—13
5	Quarantine Station, 1 mile E. of Southport.	U. S. Government	1896	0	sea level.	400	6	......	+ 0
6	Freeland	J. O. Inman	1902	......	......	about 250.	1	......	+ 3
7	Freeland, 2½ miles E. of	E. Little	1901	......	......	150	3	150	+ 2½
8	Malmo	L. Hanson	......	......	......	37?	2?	37?	— 0

CAMDEN COUNTY.

Topography.—The Pamlico terrace plain of the Pleistocene forms the entire surface of the county. This surface is very low and level, nowhere exceeding 25 feet above sea level. The highest elevation is between Lilly and South Mills in the northern part of the county. From here the plain slopes gently to the east and southeast, reaching sea level in the extreme southeast.

Geology.—Pleistocene terrace deposits of the Pamlico formation, consisting of fine sands and sandy loams, form the surface materials over the whole area. These are underlain probably in part by Pleistocene shell marl beds, and by Tertiary sands, clays, and shell marl beds believed to be in part of Miocene and in part of Pliocene age. There are no data showing the thickness of the underlying Tertiary formations, but borings at Norfolk, Va., distant 20 miles from the northern boundary of Camden County, show the Tertiary at that place to have a thickness of about 800 feet, and it is possible that a comparable thickness exists here.

Water Resources.—Over the greater part of the county shallow dug and driven wells, 7 to 13 feet deep, supply a considerable amount of soft water from the sandy beds at the base of the terrace deposits. The deeper driven wells enter the underlying shell beds and blue clay, and while yielding an abundance of water it is in many cases hard and sometimes ferruginous, and therefore unsatisfactory. The deepest

COUNTY.

Yield per minute.		How obtained at surface.	Use.	Geologic horizon and character of water-beds	Remarks.
Flow—gallons.	Pump—gallons.				
2½	....	flows.	not used.	Peedee formation; sand.	Salty water obtained at 365 ft.; flow of salty water at 719 ft. Length and size of casing: 90′-12″; 250′-10″; 719′-8″; 800′-6″.
....	....	....	abandoned.	Eocene.	
....	....	....	not used.	Cretaceous.	Basement rock struck at 1,540 ft.; strong flow at 1,442 ft. See section, p. 169. Length and size of casing: 75′-15″; 726′-12″; 1,440′?-10″; 1,440′?-8″; 1,452′-7″
....	good supply.	force pump.	domestic.	Eocene? sand.	
....	75	steam pump.	domestic.	Peedee formation; sand.	Length and size of casing: 400′-6″?; 400′—4½″. See section, p. 168. See U. S. G. S., W. S. and I. P., No. 160, 1906, p. 97.
1	....	flows.	domestic.	Peedee formation; gravel.	
½	....	flows.	domestic.	Peedee formation; sand.	
....	....	hand pump.	domestic and wood distilling.	Peedee formation? gravel and sand.	

well reported in the county has a depth of 48 feet. Overflows have never been obtained. Driven wells, locally called "pumps," are rapidly taking the place of open dug wells throughout the county. It is reported that at Lilly water is taken from the Dismal Swamp Canal for drinking and for domestic purposes. At South Mills the canal water is used only for watering stock, cistern water being used for laundry purposes, and by one family for drinking. Several families use water taken from a stream issuing from a swamp about 2 miles from the town. This water is soft and is said to be very good, but it has the dark reddish-brown color so often seen in the swamp streams of the south. Wells are also used at both these places for household purposes.

Artesian Prospects.—The porous sand beds of the underlying Pliocene and Miocene deposits should furnish an abundance of potable water. Owing to the presence of shells in many of the strata the water is apt to dissolve enough calcium salts to make it hard. There are indications that at depths exceeding 300 feet briny waters would be encountered. The water will rise near the surface in all parts of the county, but except at very low levels no flows will be obtained.

CARTERET COUNTY.

Topography.—The entire surface of the county is made up of two Pleistocene terrace plains. The first, or Pamlico plain, covers all the area to the eastward of a north-south line a few miles west of the Nor-

folk Southern Railroad, the elevations not exceeding 20 or 25 feet above sea level. The second or Chowan plain covers the remainder of the county, with elevations of 30 to 40 feet. Core and Bogue sounds are long, narrow bodies of water separated from the ocean by a nearly continuous strip of land known as the banks, which extends along the ocean front of the county. The continuity of the banks is broken only at Beaufort, and at Bogue, Whalebone, and Ocracoke inlets. Many large sand dunes have been formed on the banks.

Geology.—The surface materials over the entire county consist of Pleistocene sands, sandy loams, and clays of the Chowan and Pamlico formations. These are underlain by sands, clays, and shell marls, in part of Pliocene and probably in part of Pleistocene age. The Pliocene beds are believed to rest upon Miocene sands, clays, and marls at some depth beneath the surface, and in the western part of the county the latter rest in turn upon Eocene limestones of the Trent formation. In the extreme west the Eocene limestones occur at shallow depths beneath the surface, but dip eastward and pass beneath the Miocene.

Water Resources.—Nearly all the villages and towns of this county are situated on the lowlands bordering the coast. The inhabitants obtain their water supplies from shallow open or driven wells 7 to 35 feet in depth. Cisterns are in use at several places. Only a very few small springs are known to occur within the county. The quality of the water in the shallow wells varies considerably, but is as a rule soft. The water is reported to become brackish at times in many of the wells. In some of the driven wells the waters are ferruginous. Water assays were made of shallow well waters taken at different parts of the county. (See Table 1, pp. 492-495.)

The U. S. Life-saving Station on the banks opposite Beaufort is supplied entirely by cistern water. Water of a poor quality is obtainable here within 2 or 3 feet of the surface. Beaufort has a public fire supply consisting of three groups of wells at three of the street corners on Broad Street. There are five wells in each group: one 4-inch well in the center and four 2-inch wells surrounding it, all connected with a pipe of the same size as the fire hose. The depths of the wells are from 25 to 30 feet. The heaviest pumping by hand engines shows no diminution of supply. At the time Beaufort was visited plans were being made for the installation of eight more groups of wells.

Morehead City has six dug wells used exclusively for fire protection. The dimensions of each well are 8 feet wide by 12 feet long by 10 feet deep. The water in them usually stands within about 5 feet of the surface. They furnish large supplies of water. At one fire two of them were pumped dry by a gasoline engine, but refilled in two hours.

Deep wells have been drilled at a number of places in the county. Mr. H. H. Carr, driller, of Goldsboro, N. C., has furnished the following table of records of wells drilled at Beaufort, N. C.:

RECORD OF WELLS DRILLED AT BEAUFORT, N. C.

BY H. H. CARR.

No.	Owner.	Depth.	Diameter.	How Obtained.
1	D. Dawson Son Company	280	2 inches	Flows.
2	Town of Beaufort	280	2 inches	Flows.
3	Town of Beaufort	300	2 inches	Flows.
4	Town of Beaufort	280	2 inches	Flows.
5	Town of Beaufort	280	2 inches	Flows.
6	C. A. Clawson	280	2 inches	Flows.

In the vicinity of Stella, shell-rock probably of Eocene age is reported to underlie the surface at depths ranging from 3 to 20 feet. Water obtained below this rock is hard. Mr. J. C. Barker drilled to a depth of 78 feet at this place, and after the drill had passed through several strata of shell-rock, hard water rising to within 25 feet of the surface was obtained.

For detailed information regarding other deep wells in the county the reader is referred to the table of well data below.

Assays of waters from this county are given in Table 1, pp. 492-495, assays Nos. 29-35. These are discussed on pp. 485, 486.

Artesian Prospects.—In the west the sandy and more porous layers in the Eocene limestone and farther east the sandy strata of the Miocene and Pliocene beds are water-bearing. These horizons are reached at depths of from 30 to 300 feet. It would appear from the data contained in the accompanying tables that the principal water horizon at Beaufort lies between 270 and 300 feet below the surface, and at Morehead City between 225 and 230 feet below the surface.

CARTERET

Number.	Location.	Owner.	Date completed.	Elevation of surface above datum—feet.	Datum.	Depth—feet.	Diameter inches.	Depth to principal water supply—feet.	Height of water, ± surface - feet.
1	Beaufort	U. S. Bureau of Fisheries (Biological Laboratory).	about 1902.			235?			+ 8
2	Beaufort, at oyster cannery		about 1892.	0	sea level.	272	4		+ 6
3	Morehead City	Carteret Ice Co.	1902	12	sea level.	228	8	200	+ 0
4	do.	do.	1903	12	sea level.	226	6		+ 0
5	do.	R. W. Taylor	1899			288	4		+ 0
6	Morehead City, 1 mile E. of.	Norfolk Southern R. R. Co.	1900	6	sea level.	288	4	100	+ 0
7	Newport	W. S. Bell	1901			73	1½	73	—10

CHOWAN COUNTY.

Topography.—The surface of this county is made up of two Pleistocene terrace plains. The lowest or Pamlico plain at elevations not exceeding 25 feet covers the southeastern part of the county and is present as a belt of varying width along Chowan River to the northern boundary of the county. The second or Chowan plain covers the northeastern portion of the area and extends as a narrow ridge down through the center of the county to within a few miles of its southern extremity. The two plains are separated by a well-defined seaward-facing scarp. Just to the west of this scarp on the Chowan plain is a long, narrow ridge of sandhills averaging perhaps 10 feet above the general level of the plain. These are believed to be wind dunes formed at the time the sea margin lay along the base of the escarpment. The Chowan plain is considerably dissected by stream erosion.

Geology.—The surface materials of the county consist of sands, sandy loams, and clays of Pleistocene age which belong to the Chowan and Pamlico formations. The entire county is underlain by sands, clays, and shell marls of Miocene age whose thickness amounts to at least 500 or 600 feet. These are believed to rest upon beds of Cretaceous age.

Water Resources.—Except at Edenton, no deep wells have been drilled in this county, and the water supply is derived from open and driven wells 10 to 70 feet in depth. The water of the open wells which ranges in depth from 10 to 20 feet, and of the shallower driven wells, comes from water-bearing sands in the lower part of the Pleistocene beds. The deeper driven wells penetrate the Miocene deposits. Very few of the driven wells are over 50 feet in depth.

COUNTY.

Yield per minute.		How obtained at surface.	Use.	Geologic horizon and character of water-beds.	Remarks.
Flow—gallons.	Pump—gallons.				
5	....	flows.	used at biological laboratory.	Miocene? loose gray sand.	Flow has decreased to 1¼ gals. per minute. Varies with tide.
1¼	....	flows.	used but little.	Miocene.	Flow varies with tide; formerly owned by Gibbs Preserving Co.; see U. S. G. S. Bull. 138, p. 200.
....	75+	steam pump?	manufacture of ice.	Shell-rock.	Flow varies with tide. Another horizon at 90 ft.
....	....	steam pump?	manufacture of ice.	Miocene; fine sand.	Flow varies with tide. Another horizon at 90 ft.
....	....	....	....	Miocene; fine sand.	See water assay No. 33, table 1, pp. 492, 493.
....	abundant supply.	....	domestic.	Miocene; shells and pebbles.	Varies with tide.
....	....	....	domestic?	Pliocene?	See assay No. 34, table 1, pp. 494, 945.

At Edenton many families are using driven wells whose average depth is about 30 feet. Cisterns are also used to some extent. Some of the large manufacturing establishments take water from the bay. In a small stream valley which extends up into the center of the town, where the elevation is less than 10 feet above sea level, flowing wells are obtained at depths of from 30 to 40 feet below the surface. The wells now flow 2 to 3 gallons per minute a few inches above the surface, and it is said the water will rise 3 or 4 feet higher when confined in pipes. Wells located on the plain on which the main part of the town is built tap the same horizon, but the water will rise only to within 2 or 3 feet of the surface. Detailed information is given in the table below regarding a number of the more important deep wells at and near Edenton, and additional information is here added regarding these and other wells.

In 1893, owing to the waters of Albemarle Sound becoming brackish from protracted drouth, it became necessary to provide some other source of supply for the boilers of the mills belonging to the Branning Manufacturing Company. At their planing mill within the limits of the town of Edenton, four 2½-inch wells driven to depths varying from 62 to 65 feet furnished an abundant supply of hard, but fairly good steaming water and excellent drinking-water. These wells still supply that mill. At the other mills lying on a point of swampy land between two creeks just outside of Edenton, 28 wells were driven, striking, at a depth of from 55 to 60 feet, a scanty supply of water with an offensive odor and utterly useless for drinking purposes. The combined output of these 28 wells was not sufficient to supply the boilers. None of these were flowing wells, and in those at the mills between the

creeks the water never rose higher than within 20 feet of the surface. One of the latter was then sunk to a depth of 360 feet, but no other water horizons were encountered. This deep well was situated about midway between the deep wells at the waterworks and those at the Fish Hatchery in which flows were obtained at from 208 to 245 feet. Mr. Branning also drilled a well to a depth of 200 feet at his house on Main Street in Edenton, but failed to penetrate water-bearing beds.

In 1903, two wells 212 and 214 feet deep, respectively, and situated about 180 feet apart, were drilled for the town near the shore of the bay. (See table.) At a depth of about 200 feet a soft shell conglomerate was encountered from beneath which water issued which flowed at the surface, the combined flow of the two wells being about 20 gallons per minute. Nonflowing horizons were encountered at depths of 20, 40, and 60 feet respectively. The following year, 1904, the present water supply system was installed. The 40-foot horizon was tested with a pump having a capacity of 150 gallons per minute. It failed to supply sufficient water. The lowest horizon from which the flows were obtained was then tested and was found to furnish a combined maximum yield from the two wells of 500 gallons per minute, which was sufficient to meet the demand. The water is pumped from the wells to a nearby tank built upon a steel frame tower, which has a capacity of 65,000 gallons and which when full furnishes a pressure of 35 to 40 pounds

CHOWAN

Number.	Location.	Owner.	Date completed.	Elevation of surface above datum—feet.	Datum.	Depth—feet.	Diameter—inches.	Depth to principal water supply—feet.	Height of water, ± surface feet.
1	Edenton	Town	1903	5	sea level.	212	8	212	+1
2	do	do	1903	5	sea level.	214	8	214	+1
3	do	N. J. Hollowell	1895	5	sea level.	40	1¼	40	+ ½
4	do	Edenton Ice and Cold Storage Co.	.....	.....	a little above sea level.	53	3	53	—2
5	Edenton, 1 mile W. of	U. S. Bureau of Fisheries	about 1900.	5½	sea level.	245	2	....	+0
6	do	do	about 1900.	4	sea level.	245	6	....	+0
7	do	do	about 1900.	4½	sea level.	236	3	....	+0
8	do	do	about 1900.	4½	sea level.	236	3	....	+0
9	do	do	about 1900.	4½	sea level.	208	3	....	+0

per square inch. A direct pressure of 110 pounds per square inch can be applied from the pumps. Thirty-five thousand gallons are used daily, about one-fifth of the people in Edenton using the city supply. Three public taps flow continuously. There are about 25 fire hydrants, 112 private taps, and approximately 5 miles of mains. The wells furnish an abundant supply of water for the needs of the town. The water is hard (see Analysis No. 24, Table 2) and has a strong sulphurous odor and taste when it first issues from the wells.

One assay and one analysis of waters from this county are given elsewhere in this report, as follows: Table 1, pp. 494, 495, assay No. 36; Table 2, pp. 504, 505, analysis No. 24. These are discussed on page 486.

Artesian Prospects.—With local exceptions, an abundant supply of rather hard water is obtainable in this county at depths of from 30 to 250 feet. In many cases flows may be obtained where the surface elevations are less than 10 feet above sea level. Locally, the water is apt to contain iron salts, and in many cases it will give off the odor of hydrogen sulphide when it first issues from the wells.

It is impossible to predict with any certainty the outcome of attempts to obtain potable water at depths exceeding 250 feet. At some depth, perhaps between 500 and 600 feet, the Miocene beds would be passed through and strata of Cretaceous age entered. Waters from the latter would probably be highly mineralized.

COUNTY.

Yield per minute.		How obtained at surface.	Use.	Geologic horizon and character of water-beds.	Remarks.
Flow—gallons.	Pump—gallons.				
15	....	flows; also pumped.	city supply.	Miocene; shell-rock.	Other horizons at 20, 40 and 60 ft.
15	....	flows; also pumped.	city supply.	Miocene; shell-rock.	Other horizons at 20, 40 and 60 ft.
3	....	flows.	domestic.	Miocene; sand and gravel.	
....	....	pump.	manufacture of ice.	Miocene; sand.	Contains 386 parts per million of total solids.
4	....	flows.	not used.	Miocene.	These wells were intended to supply water for fish ponds at the fish hatcheries, but as the sulphurous water killed the young fish, all but one of the wells was abandoned, this one being used for drinking purposes. Pumping tests gave a maximum yield of 8 gals. per minute for 8 hours. Pumping one well caused other wells to cease flowing.
2	....	flows.	not used.	Miocene.	
3	....	flows.	not used.	Miocene.	
4	....	flows.	not used.	Miocene.	
5	....	flows.	drinking.	Miocene.	

COLUMBUS COUNTY.

Topography.—The surface of the county is formed entirely of Pleistocene terrace plains, which are dissected somewhat by stream erosion. There are no topographic maps of any portion of the area. From elevations obtained from railroad profiles and from field observations it has been determined that a considerable area in the northeast which extends westward along the Atlantic Coast Line Railroad as far as Whiteville constitutes a portion of the Wicomico terrace plain, at elevations of 60 to perhaps 80 feet above sea level. The next lower or Chowan plain is believed to form the surface over much of the south and southeastern part of the county. Waccamaw Lake occupies a depression in this plain, and Green Swamp, which lies to the southeast of the lake, forms a part of its area. The Wicomico plain is present also along Lumber River in the western part of the county. The Sunderland terrace plain, which is next higher than the Wicomico, is believed to cover a considerable area in the west along the line of the Atlantic Coast Line Railroad connecting Elrod and Conway, at elevations exceeding 100 feet.

Geology.—Pleistocene terrace deposits consisting of sands, sandy loams, and clays belonging to the Sunderland, Wicomico, and Chowan formations, cover the entire county. With the possible exception of the extreme northwest, where the Black Creek ("Bladen") formation may be present, the entire county is underlain by beds of the Peedee ("Burches Ferry") formation, consisting of marine sands and clays. Over considerable areas in the northeastern part of the county thin sheets of Miocene or Pliocene sands, clays, and shell marls intervene between the overlying Pleistocene deposits and the Peedee surface below. These relations have been observed on the north shore of Waccamaw Lake, along Cape Fear River, and in a number of well sections at intervening points. Miocene is mapped by Kerr along White Marsh to the west of Waccamaw Lake.

Water Resources.—In Columbus County, as in nearly all the Coastal Plain counties of the State, the Pleistocene surficial deposits offer a practically inexhaustible supply of water for general purposes. In some parts of the county these beds are relied upon for the chief supply at the present time, and in the past practically the whole county depended upon this source. The water is obtained by means of open dug wells and driven wells.

The unsatisfactory nature of shallow well waters, however, led to attempts to obtain supplies from deeper sources, and the results have been exceedingly gratifying. No county in the Coastal Plain of the State has a greater number of flowing wells. The quality of the water

is almost universally good, and much of it may be classed as excellent. A very large number of flowing wells have been obtained in the region immediately to the north of Waccamaw Lake and extending northeast to the county line, and from Lake Waccamaw westward along either side of the Atlantic Coast Line Railroad as far as Vineland, and also in a wide tract bounded on the north by the Atlantic Coast Line Railroad between the points just mentioned, on the southeast by the Waccamaw River, on the southwest by the South Carolina line, and on the northwest by a line running from Vineland to Tabor. A number of flowing wells have been obtained, also, in the extreme western part of the county in the vicinity of Fairbluff. In the eastern part of the county from Bolton eastward a number of good wells have been obtained, but except in one well at Cronly the water did not rise high enough to flow at the surface.

Detailed information has been obtained from well owners, drillers, and others regarding many of these wells. Because of the great similarity of the wells in any given community, it has seemed unnecessary to tabulate the facts concerning all of them. One or more of the more typical wells in each community have been selected and are included in the table of well data given below.

Some additional information as to the number of wells, depth, quality of the water, etc., in a number of communities is here included.

At Lake Waccamaw the wells range in depth from about 80 to 215 feet.

At Wananish the conditions are similar to those at Lake Waccamaw, although no wells have been reported exceeding 160 feet in depth. J. P. Council, who lives about one-half mile south of the railroad station, has a number of flowing wells on different parts of his plantation.

Several flowing wells have been drilled by the Carolina Trucking Development Company at Artesia.

At Hallsboro and in the immediate vicinity there are a number of flowing wells ranging in depth from 80 to 125 feet.

Many wells are reported at Vineland and the surrounding country ranging in depth from 60 to 210 feet. They flow small streams.

From Vineland southeastward to Old Dock, in the vicinity of Bug Hill, Pireway, Dothan, Guide, and Mollie, and in the intervening districts, large numbers of flowing wells ranging in depth from 100 to 200 feet have been reported. Almost every landowner has one or more wells.

At Fairbluff a number of wells 100 to 300 feet in depth having very small flows or rising nearly to the surface have been obtained.

No flowing wells have been reported from Boardman or vicinity. The Butters Lumber Company made several efforts to obtain flows, at one time driving a 1-inch pipe to a depth of 150 feet, but without success.

At Chadbourn in the years 1906 and 1907, the Independent Ice Company of Wilmington, N. C., made two attempts to obtain water for their new ice plant by drilling, the second of which was successful. In the first well the drilling was carried to a depth of 486 feet without obtaining sufficient water to supply the needs of the plant. Marine materials, consisting of sands, clays, and indurated calcareous layers, were penetrated from a depth of about 50 feet to the bottom of the well, as shown by the driller's record. These should be referred to the Peedee formation. The second well was located 150 feet from the first. At a depth of 135 feet an abundance of water was encountered in a coarse sand stratum in the Peedee formation. The diameter of this well is 10 inches. The water rises to within 12 feet of the surface. The capacity of the well was tested with a rotary pump and found to be 2,690,000 gallons per 24 hours, or at the rate of over 1,800 gallons per minute. The water is now being used at the rate of 500,000 gallons per day for the manufacture of ice.

At Cronly and at Newberlin, both in the extreme eastern part of the county, slightly salty water was obtained, the former at a depth of 278 feet and the latter at a depth of 238 feet.

The deeper wells over the greater part of the county obtain their supply from horizons in the Peedee formation. Those at Fairbluff,

COLUMBUS

Number.	Location.	Owner.	Date completed.	Elevation of surface above datum—feet.	Datum.	Depth—feet.	Diameter—inches.	Depth to principal water supply—feet.	Height of water, + surface - feet.
1	Cronly	Acme Mfg. Co.	about 1900.	15	track at railroad station.	278	2	....	+ 0
2	Newberlin	Carolina Trucking Dev. Co., Wilmington, N.C.	1907	......	about same as railroad?	238	4½	236	—28
3	Freeman, ¾ mile S. W. of P. O.	J. A. Robertson	1905	5	A. C. L. R. R.	146	2	40	— 4¼
4	Bolton	B. W. Brinkley	1901	0	track at railroad station.	165	1¼	164	— 8
5	Bolton, ½ mile E. of	Waccamaw Land and Lumber Co.	1906	......	about level of A. C. L. R. R.?	220	4	220	—12
6	Wananish, ½ mile S. of railroad station.	J. P. Council	1900	14	level of Waccamaw Lake.	160	1¼	160	+ 3
7	do	do	......	15	level of Waccamaw Lake.	150	1¼	148	+ 0
8	Lake Waccamaw	C. O. Beers	1900	65	sea level.	212	1¼	212	......
9	Lake Waccamaw, 100 yds. S. of R. R. station.	H. B. Short	1900	65	sea level.	215	1¼	214	......
10	Lake Waccamaw, ¼ mile S. of railroad station.	Atlantic Coast Line R. R.	......	about 50.	sea level.	80	1¼	....	+ 0

however, probably penetrate the underlying Black Creek formation.

Assays and one analysis of waters from this county are given elsewhere in this report, as follows: Table 1, pp. 494, 495, assays Nos. 37-51; Table 2, pp. 504, 505, analysis No. 25. These are discussed on page 486.

Artesian Prospects.—The distribution of wells as indicated in the above discussion of water conditions and in the table leads one to the conviction that the prospects for obtaining potable water from deep sources are excellent throughout most of the county. At elevations not exceeding 65 or 70 feet above sea level natural flows may in most places be obtained. At greater elevations, except possibly in the case of wells tapping much deeper horizons than have yet been reached, the water will not rise above the surface, and it will be necessary to employ pumps. There is no reason, however, why the quality should not be as good as in the case of flowing wells. It is probable that much of the western and northwestern part of the county, except the lower lands bordering Lumber River and its tributaries, is too high for flowing wells to be possible. Likewise much of the county from Bolton eastward, except in the case of lowlands along the creeks, is at too great an elevation for flows to be obtained, as shown by the negative results of a number of attempts. In the extreme eastern part of the county in the region about Cronly and Newberlin, wells exceeding 200 feet in depth will obtain a slightly brackish water, and it is believed that over other parts of the county wells exceeding 300 or 400 feet would encounter water of a similar character.

COUNTY.

Yield per minute.		How obtained at surface.	Use.	Geologic horizon and character of water-beds.	Remarks.
Flow—gallons.	Pump—gallons.				
small.	....	flows.	limited for drink. purposes.	Peedee formation; sand.	
....	2	force pump.	domestic.	Peedee formation; coarse sand.	
....	....	....	not used.	Peedee formation; sand, shells and blue marl.	Another horizon at 20 ft.
....	fair.	force pump.	domestic.	Peedee formation; sand?	
....	35 or 40	pump.	....	Peedee formation; dark gray sand.	Another horizon at 160 ft.
12	....	flows.	domestic.	Peedee formation; sand or gravel.	Other horizons at 40 and 130 ft.
7½	....	flows.	domestic and drinking.	Peedee formation; sand.	
....	....	hand pump.	domestic.	Peedee formation; sand and shells.	
....	....	flows.	....	Black Creek formation?	Flows a small stream 3 feet below surface.
3	....	flows.	drinking.	Peedee formation; sand.	

COLUMBUS

Number.	Location.	Owner.	Date completed.	Elevation of surface above datum—feet.	Datum.	Depth—feet.	Diameter—inches.	Depth to principal water supply—feet.	Height of water, ± surface feet.
11	Artesia	Carolina Trucking Dev. Co., Wilmington, N.C.	1905	71	sea level.	125	1½	122-125	+ 1
12	Hallsboro	H. B. Short, Lake Waccamaw.	1901	62	sea level.	125	1½	123-125	+ 3
13	Hallsboro, 1½ miles S. E. of.	Baldwin Brown	1902			57	1½	57	+ 3
14	Hallsboro, 2 miles N. W. of.	Thomas Brown	1880			104	1½	70±	+ 0
15	Redbug, 1 mile W. of	J. E. Thompson	1899	60?	sea level.	100	1½	90	— ½
16	Vineland	Columbus Trading Co.	1904	0	elevation at railroad station.	185	1½	185	+ 4
17	Old Dock	L. E. Thompson		15	Waccamaw River.	140?	1½		+ 0
18	do	J. G. Thompson	1897		a little above level of Waccamaw River.	150	1½	145?	+ 3½
19	Old Dock, 3 miles W. of.	Buck Clewis	1900	+ 5	level of Waccamaw River.	126	2	122	+ 5
20	Pireway	J. G. Butler	1901	+10?	level of Waccamaw River.	185	2	185	+
21	Dothan, ½ mile E. of	J. M. Butler	1896			167½	1½	167½	+ 4
22	Dothan, 2 miles S. E. of.	J. P. Butler	1898			200	2	200	+20
23	Dothan, ¾ mile N. of	W. E. Marlow & Son	1893	+40	sea level.	165	2	150	+ 3½
24	Guide	G. C. Cox	1896			190	2	190	+ 3
25	Mollie	J. F. Jacobs	1899			186	1½	186	+ 2
26	Fair Bluff	J. W. Powell	1900	65	sea level.	300	1½	200 and 300.	— 0
27	do	Town		66½	sea level.	240	1½	240	— 2½
28	Chadbourn	E. R. Bailey				45	4	45	—
29	do	Independent Ice Co., Wilmington, N. C.	1907	about 100.	sea level.	135	10	135	—12

CRAVEN COUNTY.

Topography.—Terrace plains of the Pleistocene formations form the entire surface. The lowest or Pamlico plain exists to a rather limited extent along Neuse and Trent rivers; the next higher or Chowan plain covers the greater part of the county, with elevations of 30 to 40 or 45 feet; the third or Wicomico plain, with elevations of 50 to 55 feet, is present in the extreme west, including that portion of the Great Dover Swamp which extends into the county. Considerable portions of all of these terraces are covered by swamp lands.

Geology.—Much of the county from the vicinity of New Bern westward is underlain by porous limestones of Eocene age, referable to the Trent formation. The northeastern portion is probably underlain by Miocene sands, clays, and shell marls, while that portion lying south of Neuse River estuary is underlain by similar beds of Miocene and Pliocene and possibly in part of Pleistocene age. Thin sheets of Miocene resting upon the Eocene are present over parts of the area where

COUNTY—CONTINUED.

Yield per minute.		How obtained at surface.	Use.	Geologic horizon and character of water-beds.	Remarks.
Flow—gallons.	Pump—gallons.				
1½	....	flows.	domestic.	Peedee formation; sand.	Supply has increased from ½ to 1½ gallons.
1	....	flows.	boiler and drinking.	Peedee formation; light yellow sand.	Tapped 7 ft. below surface and flows 6 gals. per minute. Another horizon at 85 ft.
½	....	flows.	domestic.	Peedee formation.	
....	....	pitcher pump.	domestic.	Peedee formation.	Flowed at first, but flow weakened and is now pumped.
....	....	suction pump.	domestic.	Peedee formation; sand and gravel.	Another horizon at 40 ft.
1½	....	flows.	drinking, etc.	Peedee formation; gray sand.	Another horizon at 64 ft.
3	....	flows.	domestic and drinking.	Peedee formation; sand.	See water assay No. 49, table 1, pp. 494, 495.
10	....	flows.	domestic.	Peedee formation.	
3	....	flows.	domestic.	Peedee formation; sand.	
22?	....	flows.	domestic.	Peedee formation; sand and gravel.	Flow has decreased.
1	....	flows.	domestic.	Peedee formation.	Flow has decreased.
10	....	flows.	domestic.	Peedee formation; shell beds.	
2	....	flows.	domestic.	Peedee formation.	
1	....	flows.	domestic.	Peedee formation; sand.	Flow has decreased.
2	....	flows.	domestic.	Peedee formation; sand.	Another horizon at 100 ft.
½	....	flows.	domestic.	Black Creek formation? sand.	Flows in pit 3 ft. below surface.
....	....	flows.	domestic.	Black Creek formation?	Another horizon at 120 ft.
....	25	gasoline pump.	laundry.	Peedee formation; sand.	
....	1,800	steam pump.	manufacture of ice.	Peedee formation; sand.	

the latter exists. All older formations are covered by thin, surficial Pleistocene deposits consisting of sands, sandy loams, and clays belonging to the Wicomico, Chowan, and Pamlico formations. The whole county is underlain beneath the Eocene and other Tertiary beds by Cretaceous marine sands and clays of the Peedee ("Burches Ferry") formation. These exist at depths perhaps not exceeding 100 feet in the northwestern part of the county, but become deeper and deeper below the surface toward the coast.

Water Resources.—The inhabitants of the smaller villages of the county and most of the farmers obtain their water supplies from shallow open and driven wells tapping the water-bearing sandy beds in the lower portion of the Pleistocene deposits. These wells range from 6 to 24 feet in depth. The driven wells average a little deeper than the dug wells. The water from some of the former is reported as ferruginous. In the larger towns there are but few open wells. Driven and drilled wells are by far the most abundant. In James City, which is situated

on a sand spit between the Neuse and Trent rivers opposite New Bern. the colored population obtain their drinking-water from shallow wells 10 to 20 feet in depth. The water here is liable to surface pollution. and all shallow open or driven wells in this place should be condemned and a supply obtained from deeper sources. Many wells have been sunk to the porous water-bearing Eocene limestones and sands and a few to Miocene beds, the latter being in the extreme northeastern part of the county. A good supply is usually obtained. Flows have been obtained only in the extreme southeast.

Detailed information regarding a considerable number of these deeper wells is given in the table of well data.

Additional notes are included regarding artesian conditions at New Bern and a number of other places.

New Bern has a water system owned and operated by the city. The plant was installed about the year 1892, but was later much improved. The supply is obtained from 6 wells each 94 feet in depth which tap the water-bearing Eocene limestones underlying the city. The wells and pumping plant are situated on the western edge of the city. The water is pumped to a standpipe of 250,000 gallons capacity, at the plant, from which it flows directly into the mains by gravity, giving when full a tank pressure of approximately 45 pounds per square inch. Connections can be made in case of fire whereby the water can be pumped directly into the mains with a pressure of 90 to 125 pounds. The wells are said to be inexhaustible, but when the pumps are run at full speed the water level can be lowered 25 feet. About 50 per cent of the inhabitants are supplied with city water. There are 750 private taps, 10 horse fountains, and 76 fire hydrants. The maximum capacity is 1,200,000 gallons per day. The Blade Lumber Company, the Pine Lumber Company, and the New Bern Cotton Oil and Fertilizer Mills each have deep wells which are connected with the city system, and in the case of an overstrain on the wells of the city waterworks these companies assist by pumping directly into the mains. In portions of the city not reached by the waterworks the city maintains public wells. Many of these are drilled wells sunk in the bottom of shallow open wells. A number of years ago a well was drilled at the pumping station to a depth of over 300 feet. Mr. A. B. Wallace, a driller at New Bern, reports that salty water was found in this well in shell-rock at about 300 feet below the surface. According to N. H. Darton,[1] the water-bearing beds at New Bern consist of alternating layers of sand and shell-rock. Large supplies of water are obtained from these shell-rock layers and water-bearing sands. The first shell-

[1] U. S. Geol. Survey Bull., No. 138, p. 199.

A.—Wooden pump used at well located on corner of Pollock, Jones, and German streets, New Bern, N. C.

B.—Open well with cypress log curb and sweep lift at Aydlett, Currituck County, N. C

rock is encountered at depths varying from 20 to 50 feet below the surface. The water rises to within 8 feet of the surface. About one-third of the houses in New Bern are supplied by drilled wells.

At Riverdale there are 5 drilled wells ranging from 55 to 100 feet in depth, the water rising to within 8 feet of the surface. The supply probably comes from beds of shell-rock.

At Croatan, two 80-foot wells are reported, the water being similar to that at Riverdale. At Blades, on Clubfoot Creek, a 4-inch well 105 feet deep flowed when first drilled.

At Tuscarora shell-rock is encountered at 25 feet below the surface and the wells range from 28 to 100 feet in depth. The upper portion of the limestone is reported somewhat porous. Water which rises to within 5 feet of the surface is obtained. At Clark and Rhems the drilled wells reach water in shell-rock at from 30 to 60 feet below the surface. At the former place the water rises to within 20 feet of the surface.

At Vanceboro an attempt to obtain artesian water resulted in securing only a small supply at a depth of 60 feet. Many thin layers of rock were passed through between 25 and 60 feet.

At Cove City water rising nearly to the surface is found in shell-rock at depths of from 65 to 110 feet.

At Dover the wells average 40 to 60 feet in depth. The water comes from shell-rock, and rises to within 10 feet of the surface. At the plant of the Goldsboro Lumber Company a well has been drilled to a depth of 210 feet. The water obtained here undoubtedly comes from the Peedee formation.

At Fort Barnwell drilled wells are reported to be rapidly taking the place of other types. Water rising to within 7 feet of the surface is found at from 55 to 120 feet below the surface.

Assays and one analysis of waters from this county are given elsewhere in this report, as follows: Table 1, pp. 494, 495, assays Nos. 52-63; Table 2, pp. 504, 505, analysis No. 26. These are discussed on page 486.

Artesian Prospects.—In the northwestern part of the county, wells 100 or more feet in depth will probably encounter water-bearing sands in the Peedee formation. These beds pass eastward, becoming deeper, but at depths exceeding 300 feet the water from them is apt to be salty. Indeed, at New Bern the water they yield is so salty that they can hardly be looked to as a source of supply. In the region about New Bern unlimited supplies of water can be secured from the shell-rock and sand layers in the Eocene at depths not exceeding 300 feet. In the southeastern part of the county abundant supplies of water may be expected from sand and marl beds of Miocene and Pliocene age.

CRAVEN

Number.	Location.	Owner.	Date completed.	Elevation of surface above datum—feet.	Datum.	Depth—feet.	Diameter—inches.	Depth to principal water supply—feet.	Height of water, ± surface feet.
1	New Bern	J. F. Taylor	1896	10	sea level.	42	2		
2	do	New Bern Cotton Oil and Fertilizer Mills.	1900	5	sea level.	56	5	56	— 5
3	do	do	1899	5	sea level.	44	1½	50?	— 4
4	do	Pine Lumber Co.	1906	10	sea level.	50	5		
5	do	W. F. Aberly		10	sea level.	50?	1½		—10
6	do	City	1902	10	sea level.	94	6		—13
7	do	do		10	sea level.	350±	8		— 4
8	do	do		10	sea level.	150	8		— 4
9	do	New Bern Ice Co.	about 1890.	10	sea level.	38	3	38	—12
10	do	do	about 1890.	10	sea level.	38	5	38	—12
11	do	do	1902	10	sea level.	65	6	65	—12
12	New Bern, 10 miles N. of	C. F. Gaskins	1898	18	sea level.	82	1½	78	—20?
13	New Bern, 8 miles N of	Alfred Gaskins		15	sea level.	60	1½		—10
14	New Bern, 9 miles N. of	Cicero Gaskins		28	sea level.	74	1½		— 8
15	New Bern, 2 miles S. W. of	J. P. Rodman		20	sea level.	72	1½	72	— 2
16	New Bern, 10 miles N. of	T. W. Price	1903	26	sea level.	42	1½		
17	James City	Munger & Bennett	1902	about	sea level.	38	6		—12
18	do	do	1906	about	sea level.	65			
19	do	New Bern Lumber Co.	1905	0	sea level.	40	6	40	—10
20	Tuscarora, 1 mile S. E. of	R. O. Adams	1903	32?	sea level.	40	2		— 8
21	Tuscarora, 1 mile S. of	D. R. Adams	1903	30+	sea level.	70	2	70	—12
22	Cove City	W. J. Brothers	1896			100	1½		— 4
23	do	W. E. White	1903			100½	1½	92	— 1½
24	Dover	Goldsboro Lumber Co.	1895	63	sea level.	210	6		—10
25	do	do	about 1901.	63	sea level.	125?	6		—15
26	do	Dover Lumber Co.	1906	62	sea level.	105	3?		—14
27	Fort Barnwell	B. B. Wooten				107	2	107	— 3
28	Croatan, 2 miles N. E. of	E. G. Welch	1906			80	2	60	—20
29	Riverdale	J. S. Fisher		24	sea level.	84	1½		—15
30	North Harlowe	Joshua Adams	1903	5	sea level.	110	3		+ 0
31	Newport	W. S. Bell	1901			73	1½		—10

COUNTY.

Yield per minute.		How obtained at surface.	Use.	Geologic horizon and character of water-beds.	Remarks.
Flow—gallons.	Pump—gallons.				
....	....	gasoline engine.	domestic.	Trent formation; shell-rock.	
....	500	steam pump.	boiler and fire protection.	Trent formation; shell-rock.	
....	250	steam jet.	boiler.	Trent formation; shell-rock.	Two wells pumped together yield 500 gals. per minute.
....	....	steam pump.	fire protection.	Trent formation; shell-rock.	Three wells; depths, 48, 49 and 50 ft. See water assay No. 59, table 1, pp. 494, 495.
....	....	windmill.	domestic.	Trent formation; shell-rock.	See water assay No. 61, table 1, pp. 494, 495.
....	....	steam pump.	city supply.	Trent formation; shell-rock.	Other horizons at 12, 15-18, 35-40 and 70. Six wells, each 94 ft. deep, are in use.
....	....	....	not used.	Trent formation?	May have reached Peedee beds.
....	....	....	not used.	Trent formation.	
....	200	steam pump.	boiler and manufacture of ice.	Trent formation; shell-rock.	See analysis No. 26, table 2, pp. 504, 505.
....	together pump 2300 gals	steam pump.	boiler and manufacture of ice.	Trent formation; shell-rock	
....		steam pump.	boiler and manufacture of ice.	Trent formation; shell-rock.	
....	....	pump.	domestic.	Trent formation; sand.	Another horizon at 36-50 ft.
....	....	hand pump.	domestic.	Trent formation? rock.	
....	....	hand pump.	domestic.	Peedee formation?	
....	....	hand pump.	domestic.	Trent formation; shell-rock.	Another horizon at 22. See water assay.
....	2	hand pump.	drinking.	Trent formation; rock.	Another horizon at 30.
....	....	force pump.	boiler.	Trent formation; shell-rock.	Hard, scales boilers. Several wells owned by company; one furnishes 750 gals. per minute. See water assay No. 55, table 1, pp. 494, 495.
....	....	force pump.	boiler.	Trent formation; shell-rock.	
....	....	steam pump.	domestic and boiler.	Trent formation; shell-rock.	
....	....	pitcher pump.	domestic.	Trent formation; white rock.	
....	....	hand force pump.	domestic.	Trent formation; rock.	
....	20	force pump.	domestic.	Peedee formation?	
....	....	hand pump.	domestic.	Trent formation?	See water assay No. 53, table 1, pp. 494, 495.
....	....	air pump.	boiler.	Peedee formation.	See water assay No. 54, table 1, pp. 494, 945.
....	....	....	not used.	Peedee formation.	
....	....	....	not used.	Peedee formation.	
....	....	....	....	Peedee formation; limestone.	
....	5	steam pump.	boiler.	Trent formation; shell-rock.	
....	....	hand pump.	domestic.	Trent formation; rock.	There are 5 wells at Riverdale, ranging in depth from 55-100 ft. Water hard and ferruginous in all.
5	....	flows.	not used.	Miocene? rock.	See water assay No. 62, table 1, pp. 494, 495.
....	....	....	....	....	

CUMBERLAND COUNTY.

Topography.—No topographic maps have been made covering areas within the limits of this county. From railroad profiles and field observations it has been determined that in the eastern and southeastern half of the county the surface is made up of three Pleistocene terrace plains. The Wicomico plain forms a bordering terrace 2 or 3 miles wide along Cape Fear River probably throughout its north-south extent within the county limits, with elevations ranging from about 90 feet in the south to perhaps 120 feet in the north. The Sunderland plain, which is separated from the Wicomico plain by a well-defined scarp, with elevations probably ranging from 130 to 150 or 160 feet, covers a large area east of Cape Fear River. This plain has been considerably dissected by streams. The Coharie plain forms the surface of much of the county to the south and west of Cape Fear River, with elevations of 160 to 220 feet. It also has been much dissected around its borders. Along the western edge of the town of Fayetteville it is separated from the Wicomico plain by a steep, well-defined escarpment. The Sunderland plain is probably absent at this place, although it may be represented by small patches. The northern and western parts of the county come within the region known as the "sandhills." The surface here consists of rolling hills with elevations of from 230 to over 400 feet.

Geology.—The Patuxent formation, consisting of arkosic sands and drab compact clays, underlies the entire county, and this in turn rests upon crystalline rocks. The beds are best exposed in the bluffs along Cape Fear River. The formation attains a maximum thickness in the southeastern part of the county of something like 300 feet. In the southeastern part of the county the Black Creek formation overlaps the Patuxent formation and rests upon it unconformably. It consists of laminated, lignitic sands and clays. The thickness probably does not exceed 100 feet within the county. Overlying the Patuxent and Black Creek formations are the surficial loams, sands and gravels of the Coharie, Sunderland, and Wicomico formations, and in the sandhill region the sands and gravels of the Lafayette formation.

Water Resources.—But few deep wells have been drilled in Cumberland County. Most of the inhabitants depend upon open and driven wells, the depths of which average 15 to 25 feet. At places open wells are not over 6 feet deep. Driven wells are in places as deep as 35 or 40 feet. On the hills west of Fayetteville and at Montrose and Inverness, where the land is higher and the relief greater, the level of ground water is lower and many of the open and driven wells are over 60 feet in depth. Most of the shallow wells obtain their supply from Pleisto-

cene sands and gravels or, in the northern and western parts of the county, from similar Lafayette materials, but a few may enter the underlying Patuxent formation. A great many springs are in use, some large, some small, issuing from the Pleistocene or Lafayette sands. The water from this source is invariably soft and low in mineral matter. The deeper wells obtain their supply either from the sandy beds of the Patuxent formation or from the underlying basement rocks.

In the included table of well data will be found the more important facts concerning the deeper wells of the county.

Fayetteville has two systems of waterworks owned by different parties. The water from one is taken from springs on Haymount Hill and distributed through the town in hollow logs now replaced in part by iron pipes. This system is owned by the Fayetteville Water, Light and Power Company. The second system is owned and operated by the city. The source of supply is a sandhill stream (Cross Creek) rising from springs in the woods, and flowing over a coarse sand and gravel bed into a small pond located 1½ miles northwest of the town. The springs issue from the sandy beds of the Coharie formation which rest upon the compact, partly indurated arkosic sands of the Patuxent formation. The water discharging at the lower end of the pond operates a small turbine which lifts a portion of the water to a standpipe on Haymount Hills, from which it is distributed through the town in iron pipes.

Several deep wells have been drilled in Fayetteville in the main part of the town. Slate is entered at from 200 to 260 feet below the surface and water is obtained within the slate. One of these wells situated on low ground has a slight overflow. No water was found in the overlying Patuxent formation, possibly owing to its compact character in this vicinity. A few open and driven wells 16 to 35 feet deep are also used.

At Hope Mills a well was sunk in the bed of Little Rockfish Creek to a depth of 175 feet. The driller reports a flow of 100 gallons a minute. The water rises 20 feet above the bed of the river. A ram is now connected to the well and supplies several houses. The ram furnishes about 1½ gallons per minute.

Assays of waters from this county are given in Table 1, pp. 494-497, assays Nos. 64-73. These are discussed on pp. 486, 487.

Artesian Prospects.—The principal artesian water horizons in Cumberland County are furnished by the Patuxent formation. Good supplies are to be expected from the more porous sand beds of this formation at moderate depths (100 to 300 feet) over most of the county. Flowing wells are possible only at low levels in the southeastern part of the county. The well at Hope Mills drilled in the bed of Little Rockfish Creek overflowed 20 feet above the bed of the creek.

The failure to obtain water in the Patuxent formation at Fayetteville is rather surprising. The probable explanation is that the materials here are too compact to permit of the free passage of the water, the spaces between the sand grains being filled with fine arkosic or clayey matter. It is to be expected, however, that coarse gravel or sand beds will be met with immediately above the basement slates, and these should be water-bearing. It is suggested that the failures may have been due to a too rapid sinking of the casing, thus shutting off flows from water-bearing beds.

CUMBERLAND

Number.	Location.	Owner.	Date completed.	Elevation of surface above datum—feet.	Datum.	Depth—feet.	Diameter—inches.	Depth to principal water supply—feet.	Height of water, ± surface—feet.
1	Fayetteville	Fayetteville Ice and Manufacturing Co.	1902	about 106.	sea level.	265	8		—1
2	do	J. M. Wright	1900	about 100.	sea level.	237	3	236	—16
3	do	W. W. Ray	1900	about 85.	sea level.	218	4		+0
4	Hope Mills	Hope Mills Manufacturing Co.	1895			170			+20
5	do	do	1895			120			
6	Manchester	?	1902	172	sea level.	125	1¼		—2

CURRITUCK COUNTY.

Topography.—The surface of the county is low and level, being included entirely within the Pamlico or lowest Pleistocene terrace plain. Except in the case of sand dunes, the elevations do not exceed 25 feet anywhere in the county. A small portion of the Dismal Swamp is included in the northern part of the county. The narrow strip of land along the coast known as the Currituck banks contains many sand dunes, some of which in the vicinity of Kittyhawk attain elevations of 80 to 90 feet. Many small sand dunes occur on the mainland in the southern part of the county.

Geology.—The sands and sandy loams of the Pamlico formation form the surface materials over the entire county, excepting, however, the relatively small areas covered by recent sand-dune materials. Sands, clays, and shell marls, probably of both Pliocene and Pleistocene age, underlie the surficial materials. Shell beds of Pleistocene age have been encountered in artificial diggings in the northern part of the county.

Water Resources.—There are no deep wells within the limits of the county. On the mainland open and shallow driven wells 8 to 20 feet

The Black Creek formation in the extreme southeastern corner of the county is a possible source of potable water, and it is not improbable that flowing wells are obtainable in the lower lands along South River.

Small supplies of water may be obtained, in places at least, from the basement rocks underlying the county at depths of 200 to 300 feet; but the uncertainty of the results of attempts to get supplies from this source, and their depth beneath the surface, render them of little importance from an economic standpoint.

COUNTY.

Yield per minute. Flow—gallons.	Yield per minute. Pump—gallons.	How obtained at surface.	Use.	Geologic horizon and character of water-beds.	Remarks.
....	4	hand pump.	drinking.	Basement slate underlying deposits of Coastal Plain.	Basement slate struck at 220 ft.
....	fair supply.	hand force pump.	domestic.	Basement slate underlying deposits of Coastal Plain.	Basement slate struck at 192 ft. See water assay No. 68, table 1, pp. 496, 497.
....	....	....	domestic.	Basement slate underlying deposits of Coastal Plain.	Will flow a little at surface.
....	....	flows.	drinking.	Patuxent formation; gravel.	See water assay No. 72, table 1, pp. 496, 497.
....	20	....	....	Patuxent formation; gravel.	
....	....	pitcher pump.	domestic.	Patuxent formation.	

in depth furnish an abundant supply of water from the lower sandy beds of the surficial Pleistocene deposits. The depth of these wells depends upon the nearness to the surface of the underlying blue clay and shell beds. In wells penetrating these shell beds a hard, ferruginous water, unfit for drinking purposes, is, as a rule, obtained. At a mill near Coinjock a well in which only hard water was obtained is reported to have been driven to a depth of 50 feet. Open wells are still much used, and predominate over driven wells in many of the villages. Terra-cotta curbing is now taking the place of the hollow cypress logs for the open wells. At Sligo cisterns are used in addition to the open and driven wells. Near Aydlett, along the sound side of the sandy stretch known locally as the "Narrow Shore," are numerous small springs the water from which is used by some of the inhabitants.

The conditions on the banks are but little different from those on the mainland. Both open and driven wells are a little shallower, running from 4 to 10 feet in depth, being deeper on the dunes than in the lower level lands. Cisterns are also used to a considerable extent. The water from the dunes is clear, while wells in the lowlands yield a highly-colored water due to the underlying marsh mud and shell deposits. Soft, fresh well water is obtainable very close to the ocean.

One assay of a water from this county is given in Table 1, pp. 496, 497, assay No. 74. This is discussed on page 487.

Artesian Prospects.—The prospects for obtaining abundant supplies of fairly potable water in this county from deep sources are good.

DARE COUNTY.

Topography.—The whole of this county, including the banks, is low, level, and swampy, nowhere, excepting in the case of wind-blown sand dunes, exceeding 8 or 10 feet above sea level. The surface forms a part of the Pamlico terrace plain, which is the lowest of the Pleistocene terraces. The chain of long linear islands called "The Banks," varying in width from a few rods to more than 2 miles, curve around the Atlantic boundary of the county. At many places along the banks immense sand dunes have been formed by the wind. These dunes reach their maximum development in the Kill Devil hills near Colington, where they attain a height of nearly 100 feet. They are bare of vegetation in most places and are constantly shifting. The sand blown from the banks is gradually shallowing Pamlico Sound for several miles off shore.

Geology.—A thin surficial covering of fine sands and sandy loams of the Pamlico formation is spread over the surface of the county. Beneath this covering there are believed to be shell marl beds of Pleistocene age having an unknown thickness, which, however, probably do not exceed 30 or 40 feet. Beneath these there come sands, clays, and shell marl beds of Pliocene age, and beneath these again, probably at a depth of 80 to 100 feet and with an unknown thickness, are similar beds of Miocene age. Roanoke Island is probably of the same age geologically as the mainland of Dare County, the Pamlico terrace materials covering its surface. Although the banks are now covered in many places by immense sand dunes of recent origin, they were probably outlined in their present position during the deposition of the beds of the Pamlico terrace.

Water Resources.—No deep wells have been drilled in this county. On Durant's Island, in Albemarle Sound, a well was driven 80 feet deep which yielded an abundant supply of water, but which was of an unsatisfactory quality. At Stumpy Point cisterns are much used, being preferred to the driven wells. The latter range from 12 to 36 feet in depth and yield a water reported to be salty. At Juniper the open wells are only 2 to 4 feet deep and water from the nearby swamps is much used. This swamp water has a dark reddish-brown color and is locally termed "juniper water." In the northern part of the mainland open and driven wells 7 to 10 feet deep are reported to furnish good water. At Manteo, the county-seat, and in the southern part of Roanoke

A.—Well sweep for lifting water from shallow dug well, Magnolia, Duplin County, N. C.

B.—Open well, showing possibilities of contamination from surface sources, located between Selma and Micro, Johnston County, N. C.

Island, cisterns rank first as a source of water supply. A few open and driven wells 10 to 15 feet deep are in use. Much of the well water has an unpleasant taste, due to decaying organic matter. The northern part of Roanoke Island is higher and sandier and driven wells 15 to 18 feet in depth yield an abundant supply of clear water.

The conditions on the banks do not differ greatly from those on the mainland. Cisterns are in most general use, since the water of the shallow open and driven wells, 3 to 10 feet deep, is usually highly colored, due to the organic content and therefore of an unsatisfactory quality. A few wells reach a depth of 18 feet. Where the wells are driven in the dune sands, however, a soft, colorless water is as a rule obtained. Because of the low elevation of the greater part of the banks, large portions of their area are often flooded during storm tides, the ground being saturated and the shallow wells filled with the salt water. It is for this reason and because of the high color and organic content of the well water that cisterns are principally used. At Avon and Hatteras it is reported that the water level in the wells varies with the tides. At Hatteras it is said that a heavy storm tide will so raise the groundwater level that pools of water will form in the lower places.

One assay and one analysis of waters from this county are given elsewhere in this report, as follows: Table 1, pp. 496, 497, assay No. 75; Table 2, pp. 504, 505, analysis No. 27. These are discussed on page 487.

Artesian Prospects.—The sandy strata of the Pleistocene, Pliocene, and Miocene beds, which constitute the underground materials to depths of at least several hundred feet, doubtless contain inexhaustible supplies of water. It is probable that wells exceeding 300 or 400 feet in depth would encounter salty water which would be unfit for domestic or manufacturing purposes.

DUPLIN COUNTY.

Topography.—The surface is made up of several Pleistocene terraces which have been dissected to some extent by stream erosion. On account of the lack of topographic maps it is impossible to determine with any degree of certainty the extent or correlation of these terraces. It is believed, however, that the Chowan, Wicomico, Sunderland, and Coharie terraces are present, the first bordering Northeast Cape Fear River, the second covering a considerable area in the east and south, the third covering nearly all of the northwestern part of the county, and the fourth covering a small area in the extreme northwestern part of the county. The southern boundary of the county to the east of Northeast Cape Fear River passes through the center of the great Angola Bay or Pocoson, a large swampy tract occupying portions of

southern Duplin and northern Pender counties. This swamp is believed to form a part of the Wicomico plain.

Geology.—The northwestern part of the county includes a portion of the belt in which surface outcrops of the laminated sands and clays of the Black Creek formation may be expected to occur. These dip to the southeastward, passing beneath the Peedee formation. The latter underlies all the remainder of the county. The Peedee materials consist of fossiliferous, dark green or gray, glauconitic, often calcareous sands, and dark marine clays. Over parts of the county there are basins or sheets of Eocene limestone or calcareous clay occupying depressions in the undulating Peedee surface, the extent and number of which cannot be determined on account of the blanket of surficial deposits. They are believed, however, not to form continuous sheets of great extent, but to exist as disconnected patches. Over at least parts of the county thin sheets of Miocene shell marl, sand, or clay, rest upon the Eocene or Cretaceous surface. Very little is known, however, concerning the extent of these. Over all older formations is spread a blanket of surficial sands and loams of Pleistocene age.

Water Resources.—Shallow open and driven wells, not exceeding 20 or 25 feet in depth and deriving their supply from Pleistocene sands and gravels, furnish a large proportion of the inhabitants with water for domestic purposes. In recent years deeper driven or drilled wells have been coming into more general use. Some of the latter derive

DUPLIN

Number.	Location.	Owner.	Date completed.	Elevation of surface above datum feet.	Datum.	Depth feet.	Diameter—inches.	Depth to principal water supply feet.	Height of water, + surface feet.
1	Branch's store	Watson Jernigan				37	1¼		
2	Bowdens	Roland Lumber Co.	1899	160±	sea level.	213	3¼		—25?
3	Magnolia	H. E. Newbury	1896	139	sea level.	230	1¼	230	—22
4	do.	J. A. Mathis	1899	139	sea level.	204	1¼	204	—28?
5	do.	do.	1900	139	sea level.	300	1¼	295	— 7
6	do.	H. M. Swinson	1900	144	sea level.	180	1¼		
7	Wallace, ½ mile S. of	Wallace Manufacturing Co.	1905	about 40.	sea level.	90	1¼		+ 0
8	Wallace, ½ mile S. W. of		1902	about 45.	sea level.	63	1¼	63	+ 2
9	Wallace, 1½ miles S. of		1898	about 40.	sea level.	74	2	74	+ 1¼
10	Hallsville	S. O. Middleton	1900	65±	sea level.	106	2	100	+ 6
11	Chinquapin	G. B. D. Parker				186	3	186	— 6
12	Chinquapin, 1 mile W. of	W. H. Sloan	1900	12	level of NE. Cape Fear R.	93	2		— 3

their supply from the Black Creek and some from the Peedee formation. Those concerning which detailed information has been obtained are included in the table below.

Some additional information is here given. In the vicinity of Wallace there are many wells which tap Peedee horizons. Those located on low ground along Rockfish and Doctors creeks furnish small flows. Those on higher ground do not flow.

At Calypso and vicinity there are a large number of wells ranging in depth from 30 to 60 feet. Those in valleys as a rule flow a small stream, while those on higher ground must be fitted with suction or force pumps.

One flowing well has been reported at Albertson. It is situated on low ground, and the water obtained is ferruginous.

Assays of waters from this county are given in Table 1, pp. 496, 497, assays Nos. 76-84. These are discussed on page 487.

Artesian Prospects.—In general it may be said that the Black Creek formation, which underlies the northwestern part of the county and passes beneath the Peedee formation to the southeastward, and the Peedee formation, which underlies the southeastern half of the county, contain abundant supplies of potable water. In most parts of the county flowing wells are possible on low ground bordering the streams, if sunk to sufficient depths. On higher ground the water will rise sufficiently near the surface to be within the reach of force or suction pumps.

COUNTY.

Yield per minute.		How obtained at surface.	Use.	Geologic horizon and character of water-beds.	Remarks.
Flow—gallons.	Pump—gallons.				
....	....	flows.	domestic.	Black Creek formation.	
....	10+	steam pump.	boiler and domestic.	Black Creek formation; sand.	See water assay No. 76, table 1, pp. 496, 497.
....	fair supply.	hand force pump.	domestic.	Black Creek formation; sand.	
....	fair supply.	hand force pump.	domestic.	Black Creek formation; sand.	
....	fair supply.	hand force pump.	domestic.	Black Creek formation; sand.	See water assay No. 82, table 1, pp. 496, 497.
....	....	hand force pump.	....	Black Creek formation; dark gravel.	
3	....	flows.	drinking and boiler.	Peedee formation; sand.	See water assay No. 84, table 1, pp. 496, 497. Another similar well.
2	....	flows.	domestic.	Peedee formation; sand.	
½	....	flows.	drinking.	Peedee formation; sand.	Has four other flowing wells.
1½	....	flows.	domestic.	Peedee formation.	Has three other similar wells.
....	....	pitcher pump.	domestic.	Peedee formation.	
....	....	pitcher pump.	domestic.	Peedee formation.	

EDGECOMBE COUNTY.

Topography.—Portions of three Pleistocene terrace plains make up the surface of this county. The Chowan plain at elevations of 30 to 60 feet borders Tar River in a belt 4 to 8 miles wide on the east and north along its entire length in the county; the Wicomico plain at elevations of 60 to 100 feet covers a belt a few miles wide in the eastern and northeastern part of the county and has a limited development along the west and south side of Tar River; the Sunderland plain, with elevations ranging from 110 to 135 feet, covers the greater part of the area west and south of Tar River, and is also present in the northern part of the county. In many places these plains are separated from each other by well-defined scarps. They are all dissected in greater or lesser degree by stream erosion.

Geology.—Granite rocks outcrop in the bed of Tar River in the vicinity of Rocky Mount. The bedrock, consisting of these granites and other crystalline rocks, dips gently to the eastward, becoming deeper beneath the deposits of the Coastal Plain. At Tarboro, crystalline schists were encountered in a well at a depth of 328 feet. Over the central and eastern portions of the county the compact, arkosic, micaceous sands and drab clays of the Patuxent formation rest upon the eroded surface of the crystallines, attaining a maximum thickness of about 290 feet at Tarboro, as shown by the deep well at that place. The upper undulating surface of the Patuxent formation rises and falls a few feet above and below water level along Tar River. Overlying the latter, and overlapping and transgressing still farther westward upon the crystalline rocks, is the Miocene, which consists in the main of stratified sands, clays, and shell marls, but along the base is made up in part of greenish, gravelly, lignitic sands and dark, lignitic, laminated clays. Pleistocene loams, sands, and gravels of the Sunderland, Wicomico, and Chowan formations blanket all older formations over the entire county.

Water Resources.—In this county the Pleistocene formations furnish most of the water for domestic use. Open and driven wells 12 to 30 feet in depth yield water from the lower sandy or gravelly portions of the terrace deposits. So compact is the sandy loam at the surface that in many places the open wells require no curbing to keep the walls intact. Along the stream slopes and scarps there are many springs of small size. These are but little used.

At Turnage, open and driven wells 8 to 25 feet deep are used. The water from the driven wells is reported ferruginous. Many of the deeper open wells enter a bluish clay containing roots and vegetable matter.

At Tarboro the first waterworks system, installed by the town in 1888 or 1889, derived its supply from Hendricks Creek, and was used for fire purposes only. This was used until 1897. In that year the Tarboro Water Supply Company installed a system, the water being obtained from wells. In November, 1899, this plant was transferred to the town. Previous to taking over this plant, the town had a deep well drilled which entered the crystalline schists underlying the deposits of the Coastal Plain at a depth of 328 feet. (See section, p. 104.) Very little water was found in this well.

The present supply at Tarboro is obtained from eleven wells situated on the east bank of Hendricks Creek. Two of these wells are 6 inches in diameter and the remainder 4½ inches. A number of wells drilled by the former company are now abandoned. Seven of the 4½-inch wells tap a water-bearing bed about 35 feet below the creek bed, while the remainder are supplied from a horizon 60 feet below the bottom of the creek. All obtain their supply from Patuxent beds. The water from the deeper horizon overflows 6 feet above the creek bed at the rate of 2½ gallons per minute from a 6-inch pipe, but will rise about 10 feet higher when confined in a pipe. The wells are all pumped together, yielding 75 gallons per minute, the water level being lowered about 13 feet by pumping. A pipe runs to the creek, and the creek water can be used in case of fire. N. H. Darton[1] refers to several wells in Tarboro drilled to depths of from 75 to 160 feet, the water of which comes nearly to the surface in the main part of the town.

A small flowing well area is located in the valley of the Tar River in the southeastern part of the county. Small flows are obtained from Patuxent horizons at from 70 to 110 feet below the surface on land less than 45 feet above sea level. The well of Mrs. W. O. Warren is reported to have flowed 15 gallons per minute when it was first drilled, but the entrance of sand into the pipes has reduced the flow to 3 gallons per minute. The flow of the well at Old Sparta has also decreased considerably.

For detailed information regarding deep wells in this county, the reader is referred to the table of well data given below.

Information concerning the water supply of Rocky Mount, which is partly within this county and partly within Nash County, is given in the discussion of the water resources of the latter county.

Assays of waters from this county are given in Table 1, pp. 496, 497, assays Nos. 85-88. These are discussed on page 487.

Artesian Prospects.—The Patuxent formation is the principal water-bearing horizon in Edgecombe County.

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[1] Bull. U. S. Geol. Survey, No. 138, p. 201.

Flowing wells from the Patuxent formation need only be expected on land less than 50 feet above sea level in the central and eastern parts of the county at depths ranging from 50 to 300 feet. On higher land, in the central and eastern parts of the county, artesian water of the same character is available at a correspondingly greater depth. While overflows are not possible on land the elevation of which is greater than 50

EDGECOMBE

Number.	Location.	Owner.	Date completed.	Elevation of surface above datum—feet.	Datum.	Depth—feet.	Diameter—inches.	Depth to principal water supply—feet.	Height of water, ± surface—feet.
1	South Rocky Mount	Rocky Mount Ice and Fuel Co.	1899	120	sea level.	754	6		
2	do	Southern Ice Co.	about 1899.	120	sea level.	280±	6		
3	Tarboro	City	1899	50	sea level.	349	8		
4	Tarboro, at waterworks plant.	City	1906	50±	sea level.	73	6	63-64	+ 2
5	Conetoe	C. W. Wilson	1905	50	sea level.	24	1½	24	—2½
6	Conetoe, 3½ miles W. of	R. C. Warren	about 1906.	41	sea level.	75	1¼	70	—6
7	Old Sparta, 2 miles S. E. of	Mrs. W. O. Warren	about 1901.	30	sea level.	84	1¼	84	2
8	Old Sparta	L. H. Wells		43	sea level.	108	1¼	100	2
9	Kingsboro, 2½ miles S. W. of.	N. C. Dept. of Agriculture (Edgecombe Test Farm).	1906	100	sea level.	169			

GATES COUNTY.

Topography.—The surface of Gates County is formed of parts of three Pleistocene terrace plains. The lowest or Pamlico plain covers a strip a few miles wide in the extreme east, with elevations not exceeding 25 feet. This area forms a part of the Great Dismal Swamp. Limited areas of this plain occur, also, along Chowan River. The second or Chowan plain, at elevations of 30 to 40 feet, covers more than half of the remainder of the county's area. It is separated from the Pamlico plain on the east by a well-defined sea-facing scarp, along whose crest is a ridge of sandhills rising about 10 feet above the level of the Chowan plain. This probably constitutes an old beach line of wind-blown sand dunes. The third or Wicomico plain, at elevations of 60 to 80 feet, is present in the northwestern part of the county. It is separated from the Chowan plain by a well-defined scarp 20 to 40 feet in height.

Geology.—Sands, sandy loams, and clays of Pleistocene age, belonging to the Wicomico, Chowan, and Pamlico formations, form the sur-

feet, the water will in all cases rise within reach of force or suction pumps.

So far as known, no wells obtain a supply from the Miocene, but it is probable that over parts of the county water could be obtained from this source. Because of their shell content, water derived from Miocene beds would probably be hard in many cases.

COUNTY.

Yield per minute. Flow—gallons.	Yield per minute. Pump—gallons.	How obtained at surface.	Use.	Geologic horizon and character of water-beds.	Remarks.
---------	---------	---------	---------	---------	No water obtained. Basement rocks entered at about 200 ft.
---------	---------	---------	---------	---------	No water obtained. Basement rocks entered at about 200 ft.
---------	---------	---------	---------	Patuxent formation; sand.	Horizons at 115-125 and 180-190 ft. Basement rocks entered at 328. Supply not sufficient and well abandoned. See section, p. 104.
5	20	gasoline pump.	city supply and boilers.	Patuxent formation; gravel and sand.	Another horizon at 42 ft. Two other similar wells used in connection with this one for city supply. See water assay No. 88, table 1, pp. 496, 497.
2	---------	windmill.	domestic.	Patuxent formation; sand.	Flows in pit 2½ ft. below surface. See water assay No. 85, table 1, pp. 496, 497.
---------	---------	pump.	domestic.	Patuxent formation; sand.	
3	---------	flows.	domestic.	Patuxent formation; micaceous fine white sand.	See water assay No. 86, table 1, pp. 496, 497.
1-9	---------	flows.	domestic.	Patuxent formation; fine white sand.	Flow has decreased. Another horizon at 14-25 ft.
---------	---------	---------	not used.	---------	

face materials over almost the entire area. These rest upon sands, clays, and shell marls of Miocene age. The thickness of the latter is unknown, but it is believed to be something like 400 feet in the extreme west and perhaps 600 feet in the extreme east. The Miocene beds rest unconformably upon the buried surface of Cretaceous beds.

Water Resources.—No deep wells have been drilled in this county. The water-bearing sand beds in the lower part of the Pleistocene formations yield an abundant supply of water which is obtained by means of shallow open and driven wells 6 to 20 feet in depth, which are in common use. A few wells have been driven to depths of from 36 to 60 feet at Gatesville, Hobbsville, Reynoldson, Sunbury, and Trotville, obtaining water from Miocene beds. As far as known, no overflow wells exist within the county limits.

One assay of a water from this county is given in Table 1, pp. 496, 497, assay No. 89. This is discussed on page 487.

Artesian Prospects.—The sandy beds of the underlying Miocene in all probability carry abundant supplies of water. It is just possible

that potable waters might be obtained from deep-lying Cretaceous beds at depths of 500 feet or over, but the quality of water from this source remains to be tested. Flowing wells are not believed to be possible except in low lands bordering Chowan River and its tributaries. In wells whose depths do not exceed 300 feet below the surface the water would probably not rise more than 10 feet above sea level. At greater depths it would rise somewhat higher. Gatesville is probably the only town so situated that an overflow would be possible from either the Miocene or Cretaceous beds.

GREENE COUNTY.

Topography.—Parts of three Pleistocene terrace plains make up the surface of this county. The Chowan plain forms narrow borders along Contentnea and Little Contentnea creeks at elevations ranging from 30 to 60 feet; the Wicomico plain at elevations of 60 to 90 feet covers the interstream areas of a little more than half the county on the east; while the Sunderland plain, with elevations of 110 to 120 feet, forms the surface over a little less than half the county in the west. In places the plains are separated by well-marked scarps. The plains have been dissected somewhat by stream erosion.

Geology.—The county is underlain by the Patuxent and Black Creek formations, and to a limited extent by the Peedee sand, of Cretaceous age, and in part by Miocene beds which overlap the Cretaceous. The Patuxent formation underlies a narrow area extending in a northeast-southwest direction in the northwestern part of the county. It here rests upon a buried crystalline surface which probably lies at a depth of about 200 feet and which becomes deeper to the southeast. The Patuxent beds consist of compact, drab, sandy clays, and gray, micaceous, arkosic sands. These dip gently to the southeast and pass unconformably beneath the Black Creek formation. The latter, which consists in part of dark-colored, laminated, lignitic sands and clays, and in part of marine greensands, underlies a wider belt extending in a northeasterly direction across the center of the county. It dips gently to the southeast and passes conformably beneath the Peedee formation. The latter underlies a limited area in the southern part of the county. The beds are composed of dark green, glauconitic sands and clays, with occasional layers of lime concretions. Resting upon the undulating surface of the Cretaceous and probably spreading over almost the entire county are beds of Miocene age consisting of loose, light-colored sands, sometimes iron-stained and indurated, and light drab clays, frequently fossiliferous. Pleistocene deposits of the Sun-

derland, Wicomico, and Chowan formations, consisting of yellowish sands or sandy loams, with coarser sands and gravels at base, form the surface materials over all the county.

Water Resources.—The sands and gravels in the lower parts of the Pleistocene formations furnish most of the water supply for the inhabitants of Greene County. Open and driven wells 10 to 30 feet deep are used. The compactness of the overlying sandy loams makes it unnecessary to curb the open wells to keep the walls intact.

Two flowing well areas have been developed in the county. One borders Contentnea Creek in the vicinity of Speights Bridge, and is a continuation of the flowing well area near Stantonsburg in Wilson County. The other is about 4 miles southeast of Snow Hill. In the Speights Bridge area the flowing wells range from 110 to 137 feet in depth, with flows of from 6 to 35 gallons per minute. It is stated that in most of the wells sunk in this area the water will rise 10 to 12 feet above the surface. The water is said to have a rather strong sulphurous odor when the wells are first drilled, but this decreases after they have flowed a short time. All of the flows now have a very faint sulphurous odor. The water-bearing horizons occur in the Patuxent formation. Within this area flows are not obtainable at an elevation of over 70 feet above sea level. A well sunk near here on one of the outliers of the 110-foot terrace did not reach the artesian water horizon until a depth of about 200 feet had been attained and the water came to within about 40 feet of the surface.

In the flowing well area 4 miles southeast of Snow Hill the water-bearing horizon is in the Black Creek formation. The elevation of the surface is about 40 feet above sea level and the water-bearing beds are encountered at from 64 to 84 feet below the surface. Flows of from 2 to 13 gallons per minute have been obtained. The head is sufficient to make the water rise 8 feet above the surface. In drilling, large pieces of lignite are found a short distance above the water-bearing beds.

Several attempts have been made to get flowing wells at Snow Hill, but the elevation of most of the town is so great that flows are not to be expected except in the bottom of the stream valleys near Contentnea Creek and on the lowlands bordering Contentnea Creek. Mr. B. W. Edwards had a well drilled to a depth of 145 feet at a point the elevation of which was 80 feet above sea level. But little water was found. In 1906 Mr. Edwards had a second well drilled, located on much lower ground. A very small flow was struck at 90 feet and another at 110

feet below the surface. It is probable that had the well been located on still lower ground the flow would have been considerably stronger.

Eight miles east of north of Snow Hill, Mr. D. W. Patrick obtained an ample supply for boilers at a sawmill and cotton gin at a depth of 90 feet. Coming from just below a shell marl, the water was hard. Drilling was continued to a depth of 153 feet, at which depth soft water was found. The 90-foot water alone was used.

At Jason several wells have been drilled and soft water obtained from the Black Creek formation. Overflows are not possible here on account of the elevation.

The deep well at Ormondsville was drilled with the expectation of getting a flow. None was obtained, but the water rose within reach of a pitcher pump. Overflows are not probable in this vicinity.

At Ridges Spring a depth of 80 feet had been reached when an indurated layer was struck and drilling stopped. Overflows could probably be obtained in the lowlands bordering the stream here at a depth of 100 to 150 feet below the surface.

GREENE

Number.	Location.	Owner.	Date completed.	Elevation of surface above datum—feet.	Datum.	Depth—feet.	Diameter—inches.	Depth to principal water supply—feet.	Height of water, ± surface—feet.
1	Snow Hill	B. W. Edwards		80?	sea level.	145	3		
2	do	do	1906	40?	sea level.	125	1¼	110	+ 6
3	Snow Hill, 8 miles E. of N. of.	D. W. and J. M. Patrick	1902	83	sea level.	153	2	90	—18
4	Snow Hill, 4 miles S. E. of.	R. C. Rouse	1905	40±	sea level.	64		64	+ 2
5	do	do	1905	40±	sea level.	68	1¼	68	+ 2
6	do	T. R. Tyndall	1905	40±	sea level.	78	1¼	78	+ 0
7	do	W. H. Hill	1905	40±	sea level.	83	1¼	83	+ 0
8	do	Mrs. Elbert Edwards	1906	40±	sea level.	84	1¼	84	+ 0
9	do	Union Chapel	1905	40±	sea level.	70	1¼	70	+ 2
10	Speights Bridge	Wiley Webb		60	sea level.	120	1¼	120	+ 0
11	do	P. W. Ward		58	sea level.	110	1¼	110	+ 0
12	do	J. L. Bynum		56	sea level.	110	1¼	110	+ 0
13	do	do		58	sea level.	124	1¼	124	+ 0
14	do	do		55	sea level.	130	1¼	130	+ 0
15	do	do		58	sea level.	136	1¼	136	+ 0
16	do	do		58	sea level.	137	1¼	137	+ 0
17	Jason	W. D. Cobb	1906			102	2	102	— 0
18	do	C. H. Swinson	1905			47	1¼	47	—12
19	Ormondsville	Turnage & Ormonds	1904			158	1¼		—20

Assays of waters from this county are given in Table 1, pp. 496, 497, assays Nos. 90, 91. These are discussed on page 487.

Artesian Prospects.—Flowing wells are possible at moderate depths, 75 to 150 feet, in the lowlands bordering the streams over the entire county. Along Contentnea Creek near Speights Bridge in the northwestern part of the county it is doubtful if flows can be obtained at elevations greater than 70 feet. The lower the land the greater will be the flow in most cases. Farther down the stream in the region southeast of Snow Hill the flows come from a horizon in the Black Creek formation. On the high land in the interstream areas the same artesian water horizons will be reached at a slightly greater depth, and in most if not all cases the water will rise within reach of pitcher pumps.

In the extreme southeastern corner of the county shallow drilled wells may possibly obtain hard water, but if the drilling is carried to greater depths softer water should be found. In the higher interstream areas nonflowing waters may be expected from the Miocene beds which overlie the Cretaceous.

COUNTY.

Yield per minute.		How obtained at surface.	Use.	Geologic horizon and character of water-beds.	Remarks.
Flow—gallons.	Pump—gallons.				
....	....	....	not used.	Black Creek formation?	
½	....	flows.	....	Black Creek formation?	
....	10	steam jet.	boiler.	Black Creek formation? gravel.	Another horizon at 153 ft.
13	....	flows.	domestic.	Black Creek formation; sand.	
4	....	flows.	domestic.	Black Creek formation; sand.	
2	....	flows.	domestic.	Black Creek formation; sand.	
6	....	flows.	domestic.	Black Creek formation; sand.	
3	....	flows.	domestic.	Black Creek formation; sand.	
2½	....	flows.	domestic.	Black Creek formation; sand.	
20?	....	flows.	domestic.	Patuxent formation; sand?	
6	....	flows.	domestic.	Patuxent formation; sand?	
10	....	flows.	domestic.	Patuxent formation; sand?	
about 10	....	flows.	boiler.	Patuxent formation; sand?	
30	....	flows.	domestic.	Patuxent formation; sand?	
6	....	flows.	domestic.	Patuxent formation; sand?	
35	....	flows.	domestic.	Patuxent formation; sand?	
....	5	force pump.	domestic.	Black Creek formation; sand.	
....	2	hand pump.	domestic.	Black Creek formation; coarse red sand.	
....	....	pitcher pump.	domestic.	Black Creek formation.	

HALIFAX COUNTY.

Topography.—No part of the county is covered with topographic maps, and an accurate statement of the surface features is impossible. The Chowan terrace plain of the Pleistocene borders Roanoke River, with elevations not exceeding 50 or 60 feet; a considerable portion of the eastern part of the county is covered by the next higher or Wicomico plain, with elevations ranging from 80 to perhaps 100 feet, being separated from the Chowan plain by a well-marked scarp; in the central part of the county the Sunderland plain exists, but its extent is not known; and a narrow strip of the Coharie plain is probably present to the west of the Sunderland area. The western part of the county falls within the Piedmont region and presents a Piedmont topography, although deposits of Lafayette age are present to greater or lesser extent as surficial coverings.

Geology.—Crystalline rocks form much of the surface in the western part of the county, reaching elevations of perhaps 400 or 500 feet. To the eastward the surface of the crystallines passes beneath the deposits of the Coastal Plain, forming their basement, and in the extreme east probably exist at a depth of about 400 feet. In that part of the county lying to the east of the main line of the Atlantic Coast Line Railroad the Patuxent beds, consisting of compact clays and arkosic sands, are present, resting directly upon the eroded crystalline surface. These reach a maximum thickness of perhaps 275 to 300 feet. Their upper undulating surface was observed rising and falling above and below water level in Roanoke River from the State farm to Palmyra, the maximum thickness exposed being about 12 feet. Resting upon the latter are the sands, clays, and marls of the Miocene, having a maximum thickness of perhaps 75 or 80 feet, and spreading westward beyond the region of the Patuxent beds, overlapping and transgressing upon the crystalline basement surface to an unknown distance, perhaps not exceeding a few miles west of the main line of the Atlantic Coast Line Railroad. Over all older formations the Pleistocene sands, loams, and gravels of the several terrace deposits are spread in a thin sheet, even extending westward over the crystalline rocks. In the western part of the county deposits of sand and gravel of Lafayette age mantle to greater or lesser extent the Piedmont hills at elevations exceeding 230 feet above sea level.

Water Resources.—Over the eastern half of the county the drinking-water is obtained principally from open and driven wells 15 to 50 feet in depth, the water coming from the lower sandy portions of the Pleistocene, or in the deeper wells from sand beds in the Miocene. The most common depth of the driven wells is about 30 feet. Where stream

cutting has been deep, as at Halifax, the wells must be sunk deeper before reaching the level of ground water. Springs are abundant, but small, and are little used.

In the western half of the county the crystalline rocks, where not outcropping, are close to the surface, and the wells at many places enter their upper decomposed portions. Owing to the greater relief, the level of ground water is in many places at a considerable depth beneath the surface, and dug wells in places reach a depth of 80 feet. Open wells are mostly used, driven wells being restricted to areas covered by remnants of the Coastal Plain deposits. A good many springs are used in this section of the county. At Sunlight the engines on the Seaboard Air Line Railway are supplied from a spring.

Deep wells which enter the underlying crystallized rocks and derive a supply of water from them have been drilled at Scotland Neck, Enfield, and Halifax. A much softer water was thus obtained at Halifax, and the people depend mostly upon this deep well, although a few dug and driven wells are in use. At Enfield two attempts to obtain artesian water were made a few years ago with a hand drilling machine, but in each case drilling ceased when the rock was reached. A small amount of water was found at 20 feet and just above a 10-foot bed of Miocene shell marl at 60 feet. The water from the latter horizon was of an unsatisfactory quality. Below the shell marl, red clay extended down to the bedrock. Later, about 1900, two deep wells were put down about 450 yards apart. In one of these, the town well, the water is reported to come chiefly from a crevice at 160 feet. In the other, the graded-school well, a crevice encountered at 115 feet hung the drill and prevented further drilling. The water of these two deep wells is used by many of the people for drinking purposes. There are, however, many driven wells 18 to 20 feet deep in use. The town owns 20 open wells averaging about 20 feet in depth, which are used for fire protection. Those recently dug are about 8 feet square. Two of the earlier ones are at least 12 feet square. One gasoline and one hand engine are used for fire purposes. The gasoline engine can exhaust one of these in one-half hour, but it will refill in about the same length of time. Thus far there has been sufficient water for fire protection.

At Norfleet, situated on the Chowan terrace, a well was sunk to a depth of 225 feet. Water encountered at 170 feet rose within 8 feet of the surface. Hoping that a larger supply would be obtained, drilling was continued to a depth of 225 feet, but without success, and the casing was pulled back to 170 feet.

At Rosemary, a small town in the northern part of the county, water

is taken from wells 75 to 156 feet in depth drilled in the crystalline schists. There are about 15 of these in use. The rock is entered at from 30 to 80 feet below the surface.

At Roanoke Rapids, in many wells 4 to 6 inches in diameter and 60 to 108 feet in depth, the water is obtained from the crystalline schists which lie 20 to 30 feet below the surface of the town. These wells yield from 9 to 35 gallons of soft water per minute. Many open wells 12 to 20 feet in depth are in use, the water coming from the basal gravelly beds of the terrace deposits. The water level in the drilled wells stands about 12 to 14 feet below the surface.

At Weldon, the bedrock is struck about 35 feet below the surface, water being obtained just above the surface of the crystallines. A few of the wells enter the rock, the deepest being that of Mrs. S. A. Ransome, drilled in 1896 to a depth of 90 feet. In most of the wells force pumps are necessary, the nearby deep valley of the Roanoke lowering the level

HALIFAX

Number.	Location.	Owner.	Date completed.	Elevation of surface above datum—feet.	Datum.	Depth—feet.	Diameter—inches.	Depth to principal water supply—feet.	Height of water, ± surface feet.
1	Norfleet	Patapsco Guano Co., Baltimore, Md.	about 1904.	about 50.	sea level.	225	2½	170	— 8
2	Scotland Neck	Town	1902	90±	sea level.	607	6	....	—35
3	Enfield	Town	about 1900.	100	sea level.	200	4	....	—10
4	...do	Graded school	about 1900.	100	sea level.	115	4	....	—15
5	Halifax	County	1900	100	sea level.	270	8	....	—80
6	Tillery, 4 miles E. of	State farm	......	......	....	80	....	80	......

HARNETT COUNTY.

Topography.—The topographic features of this county are but imperfectly known, owing to the lack of topographic maps. The Coharie terrace plain of the Pleistocene probably covers a limited portion of the area in the southeast at an elevation of about 220 feet. Much of the county west of Cape Fear River falls within the so-called sandhill belt, whose elevations range from about 220 to 400 or 500 feet.

Geology.—Basement rocks form the surface or occur immediately beneath a thin mantle of Lafayette sands and gravels over much of the northern third of the county. Southward they pass beneath the deposits of the Coastal Plain, becoming deeper and deeper beneath the surface. Over about the southern half of the county the drab clays and arkosic sands of the Patuxent formation rest upon the uneven

of ground water beyond the reach of suction pumps. No analyses of the well waters at this place were obtainable, but it is reported that the quality varies considerably. A canal feeding from higher up the Roanoke River furnishes power to some of the mills at Weldon.

The table given below furnishes detailed information of a number of the deep wells of the county.

Assays and analyses of waters from this county are given in this report, as follows: Table 1, pp. 496, 497, assays Nos. 92-95; Table 2, pp. 506, 507, analyses Nos. 28-30. These are discussed on page 488.

Artesian Prospects.—Flowing wells are not possible in Halifax County, unless it be on the lower lands bordering the Roanoke River and Fishing Creek and their tributaries in the extreme southeastern corner of the county. Over the eastern half of the county good supplies of artesian water are obtainable from the Miocene and Patuxent beds at from 60 feet near Enfield to 200 feet in the southeastern corner.

COUNTY.

Yield per minute.		How obtained at surface.	Use.	Geologic horizon and character of water-beds.	Remarks.
Flow—gallons.	Pump—gallons.				
....	8½	windmill and gasoline engine.	domestic and stock.	Patuxent formation; small pebbles and black sand.	Other horizons at 0-60 ft.
....	2	force pump.	drinking.	basement rock.	Basement rock struck at 349 ft. Another horizon at 120 ft.
....	....	force pump.	drinking.	basement rock.	Basement rock struck at 109 ft. See water assay.
....	....	force pump.	drinking.	basement rock.	Basement rock struck at 90 ft. See water assay.
....	....	force pump.	drinking.	basement rock.	Basement rock struck at 40 ± ft.
....	15	pump.	....	Patuxent formation; gravel.	

basement rock surface, and along the extreme southern border perhaps exceed 100 feet in thickness. In a limited area a few miles to the northeast of Spout Springs there exists a remnant of siliceous Eocene limestone resting upon the Patuxent beds at an elevation of perhaps 300 feet. In the sandhill region, and to greater or lesser extent in the area of crystalline outcrop, the surface is blanketed with sandy clays, sands, and gravels of the Lafayette formation. In the southeastern part of the county loams, sands, and gravels of the Coharie and Sunderland formations of the Pleistocene form the surface materials.

Water Resources.—But three deep wells have been drilled in Harnett County, and each of these has entered the underlying rocks at less than 150 feet below the surface. The water obtained in each case is slightly hard. Assay 96, Table 1, pp. 496, 497, is a test of the deep well at Dunn.

The water for family use on the farms and in the small villages scattered throughout the county is obtained almost entirely from open wells and springs. Only a few driven wells are in use. Springs are abundant, are often very large, and are much used. The village of Spout Springs is said to derive its name from an old spring which issued through a small spout. The open wells range in depth from 10 to 80 feet, most of them being less than 40 feet. Many of these enter the underlying basement rocks, the water coming from seams in the rock.

HARNETT

Number.	Location.	Owner.	Date completed.	Elevation of surface above datum—feet.	Datum.	Depth—feet.	Diameter—inches.	Depth to principal water supply—feet.	Height of water, ± surface—feet.
1	Dunn	Town	1903	208		434	*	434	—12
2	Cambro	Harnett Lumber Co.	1902			255	8		—30
3	Duke	Erwin Cotton Mills Co.	1906	170	elevation of water in Cape Fear River.	501½	8	363	—99

*10 inches at top; 8 inches at bottom.

HERTFORD COUNTY.

Topography.—The surface of the county is formed of Pleistocene terrace plains. Small areas of the Pamlico plain, with elevations not exceeding 20 or 25 feet, are present along Chowan and Meherrin rivers and some of their creek tributaries; the Chowan plain, with elevations of 30 to 50 feet, covers the greater part of the eastern half of the county; while the Wicomico plain, with elevations of from 70 to perhaps 80 feet, covers about the western half of the county and a portion of the extreme southeast. The several terraces are separated from each other by well-defined escarpments. The several plains have suffered dissection by stream erosion in greater or lesser degree.

Geology.—Deposits of Miocene sands, clays, and shell marls underlie the entire county. These rest upon a buried surface of Cretaceous strata. In the western part of the county this surface would probably be encountered at a depth of from 100 to 200 feet, and in the extreme east at from 500 to 600 feet. Pleistocene terrace deposits consisting of sandy loams, sands, and clays which belong to the Wicomico, Chowan, and Pamlico formations, form a surficial covering over the Miocene beds.

Water Resources.—The principal part of the water supply of this county comes from open and driven wells 12 to 40 feet in depth,

Assays of waters from this county are given in Table 1, pp. 496, 497, assays Nos. 96, 97. These are discussed on page 488.

Artesian Prospects.—The thinness and disconnected character of the Coastal Plain sediments over much of the county render them unimportant as sources of artesian supplies. Along the southern border of the county, however, where the Patuxent formation is thickest its beds may be expected to furnish fair supplies at depths not much exceeding 100 feet, and it is barely possible that at low levels close to the streams flows may be obtained.

COUNTY.

Yield per minute. Flow—gallons.	Yield per minute. Pump—gallons.	How obtained at surface.	Use.	Geologic horizon and character of water-beds.	Remarks.
---------	about 200	steam pump.	city supply.	basement rock.	Basement rock struck at 90 ft. See water assay, pp. 496, 497.
---------	100?	force pump.	domestic and manufacturing.	basement rock.	
---------	65	force pump.	domestic.	basement rock.	Basement rock struck at 143 ft.

although a few of the driven wells reach 60 feet. The water comes from the lower sandy portions of the Pleistocene formations or in the deeper wells from the upper sandy beds of the Miocene. Along the scarps where the lower sandy beds of the Pleistocene formations rest upon the more compact Miocene beds, as at Winton, numerous small springs occur. These are, however, but little used.

At Winton two deep wells have been drilled, one of which, situated on low land near the Chowan River, has a flow of about 1 gallon per minute from a depth of 135 feet. In this well a small overflow was also obtained at about 100 feet. The other well, drilled to a depth of 165 feet in the main part of the town on the Chowan terrace, encountered the same water-bearing strata. Not obtaining a flow, the well was not used for a considerable length of time, and when attempts were made to pump it, the pipe was found to be full of sand.

The only other drilled well in the county is at Tunis, the situation of this well being similar to that of the flowing well at Winton. A flow was struck at 165 feet, but the casing was driven only 130 feet. The well flowed about four months, the flow gradually decreasing until, on account of a cave-in between the end of the casing and the water-bearing stratum, the flow ceased. In the fall of 1906 the well was cleaned out and now has a flow of about ¾ gallon per minute.

One assay and three analyses of waters from this county are given elsewhere in this report, as follows: Table 1, pp. 498, 499, assay No. 98; Table 2, pp. 506, 507, analyses Nos. 31-33. These are discussed on page 488.

Artesian Prospects.—The sandy beds of the Miocene contain an abundance of potable water which is sometimes hard, owing to the presence of Miocene shell marl beds.

HERTFORD

Number.	Location.	Owner.	Date completed.	Elevation of surface above datum—feet.	Datum.	Depth—feet.	Diameter—inches.	Depth to principal water supply—feet.	Height of water, ± surface—feet.
1	Tunis	K. R. Israel	1906	5	sea level.	165	1½	165	+ 2
2	Winton	S. P. Taylor	1905	45	sea level.	165	1½	165	—33
3	....do	W. P. Taylor	1905	0	sea level.	135	1½	135	+ 4

HYDE COUNTY.

Topography.—The surface of the entire county is low, nowhere exceeding 15 feet in elevation above sea level. It forms a part of the Pamlico terrace plain, which is the lowest of the Pleistocene terraces. The highest land is reported to be in the vicinity of Pungo Lake in the northwest corner of the county. Much of the county is covered by peaty swamps. Salt marshes border the coast everywhere. Mattamuskeet Lake, 16 miles long by 5 miles wide and 4 feet deep, lies in the center of the county. Alligator Lake, a much smaller lake, 3 to 5 feet deep, is in the northern part of the county. Low ridges surround these lakes. According to legend, the lake depressions were formed by the burning of peat bogs. They may, however, be original depressions in the surface of the terrace plain.

Geology.—Fine sands, sandy loams, and clays belonging to the Pamlico formation constitute the surface materials over all the county. These rest upon sandy clays and shell marls believed to be of Pleistocene age. The latter rest in turn upon similar Pliocene beds. The combined thickness of the Pliocene and Pleistocene beds is thought to amount to about 80 to 100 feet. Beneath the Pliocene beds are similar beds of Miocene age which have an unknown thickness. (See section of well at Lake Landing, p. 252.)

Water Resources.—Cistern water is used by many of the inhabitants of the county. A few shallow open wells 6 to 15 feet in depth are in use, but almost everywhere in the county water from this source is re-

The depths at which the basal Cretaceous beds would be encountered can only be determined by drilling. In the extreme western part of the county it is probable that they would be reached somewhere between 100 and 200 feet below the surface. Eastward they become deeper, and in the extreme east probably occur at a depth of 500 feet or over. There is good reason to believe these beds would prove to be the source of water of excellent quality.

COUNTY.

Yield per minute. Flow—gallons.	Yield per minute. Pump—gallons.	How obtained at surface.	Use.	Geologic horizon and character of water-beds.	Remarks.
¼	....	flows.	drinking.	Miocene; fine white sand.	Will rise to 12 ft. above sea level. Another horizon at 130 ft. See water assay No. 98, table 1, pp. 498, 499.
....	....	....	not used.	Miocene; white sand.	Another horizon at 130 ft.
1	....	flows.	domestic.	Miocene; fine white sand.	Will rise to 10 ft. above sea level. Another horizon at 105 ft.

ported unsatisfactory. However, on the low ridge surrounding Lake Mattamuskeet some fairly good shallow well water is obtained.

At Fairfield the landholders have cisterns, but the tenants use open wells. The water from the latter is unsatisfactory. Some of the dug wells a short distance from Fairfield furnish dark, reddish-brown water, the color being due to vegetable matter. Similar colored waters are obtained at Middletown and Engelhard, where it is used chiefly for watering stock. Storm tides flood a considerable portion of the section around Middletown, at which times wells in the flooded areas are filled with salty water. In shallow wells located near the shores of the sound the level of ground water is said to vary with the tide. At Ocracoke on the banks the land is low and the shallow well water salty and unsatisfactory. Cistern water only is used here.

Many deep wells have been drilled in the more thickly settled parts of the county. Small flows are obtained at some places, and in all cases where flows do not occur the water rises to within a short distance of the surface. Detailed information has been obtained concerning a considerable number of the deep wells, and this has been arranged in tabular form. (See table below.)

Middletown is well supplied with artesian water. That from the deeper horizons, after first reaching the surface, emits an odor of hydrogen sulphide. The high iron content renders much of the deeper water unsatisfactory for cooking and laundry purposes.

At Engelhard the conditions are about the same as at Middletown.

At Fairfield two wells which exceeded 200 feet in depth each encountered slightly salty water.

There are many wells in the vicinity of Swanquarter which range in depth from 75 to 200 feet, the water as a rule being slightly sulphurous.

For information regarding some of the original wells drilled in this county, see Darton's report, U. S. Geological Survey Bulletin, No. 138, pp. 197-198.

HYDE

Number.	Location.	Owner.	Date completed.	Elevation of surface above datum—feet.	Datum.	Depth—feet.	Diameter—inches.	Depth to principal water supply—feet.	Height of water, ± surface—feet.
1	Engelhard	J. M. Clayton	1889	2½	sea level.	266	1½	266	+ ½
2	Engelhard, 2 miles N. E. of	Davis & Spencer	1906	1	sea level.	140	1½	100	+2
3	Engelhard, ½ mile S. E. of	do	1898	1	sea level.	140	1½	130	+2½
4	Engelhard, 1 mile S. of	J. C. Respess	1906	4	sea level.	220	1½	123	+0
5	Middleton	County	1893?	2	sea level.	213	2	213	+ ½
6	do	B. F. Cox				204	1½	204	+ 5/6
7	do	C. Davis	1897	2	sea level.	212	1½	212	+0
8	do	J. S. Mann	1898			210	1½	210	+0
9	do	E. L. Gibbs	1900	3	sea level.	220	1½		+1
10	do	J. M. Hall	1893			196	1½	196	+ ½
11	do	J. O. Marshall	1893			207	2	207	—1
12	do	R. E. Cox	1895			224	1½		+0
13	Middleton, 1 mile S. E. of	C. F. Farrow	1904	3	sea level.	230	1½	175	+ ½
14	Middleton, 2 miles N. of	W. P. Burrus	1904	4	sea level.	230	1½		— ½
15	Middleton, 2 miles S. W. of	J. G. Young	1898	4	sea level.	185	1½	165	—1
16	Wysocking, ½ mile S. of	O. T. Credle	1894	3	sea level.	100	2		—5?
17	Wysocking, 2 miles E. of	W. R. Gibbs	1906			152	2	152	+1½
18	Wysocking	George I. Watson	1895	7	sea level.	173	1½	173	—8
19	Wysocking, 1½ miles E. of	W. D. Mann	1905	7	sea level.	137	1½		—1½
20	Lake Landing, 2 miles E. of	W. S. Jennett	1894	10	sea level.	246	1½		—4
21	Lake Landing, 1 mile S. W. of.	H. B. Spencer	1896	3	sea level.	200	1½		+0
22	Lake Landing, 2½ miles S. E. of.	J. W. Bennett	1904	1½	sea level.	205	1½		+ ½
23	do	W. R. Gibbs				200			
24	Fairfield	J. C. Burrus	about 1904.			80	2	75–80	—2
25	do	do	about 1904.			80	2	75–80	—2
26	do	J. A. Mann	1904			240			+4

Assays and analyses of waters from this county are given elsewhere in this report, as follows: Table 1, pp. 498, 499, assays Nos. 99, 100; Table 2, pp. 506, 507, analyses Nos. 34, 35. These are discussed on page 488.

Artesian Prospects.—Experience has demonstrated that potable waters are obtainable in most parts of the county at depths ranging down to 250 feet. Drilling to much greater depths than this would probably encounter water too salty to be of use for ordinary purposes.

COUNTY.

Yield per minute. Flow—gallons.	Yield per minute. Pump—gallons.	How obtained at surface.	Use.	Geologic horizon and character of water-beds.	Remarks.
....	....	pitcher pump.	domestic.	Miocene; gravel.	
2	....	steam pump.	domestic and boiler.	Miocene; gravel, shells, rock and sand.	Another horizon at 30 ft.
....	....	steam and hand pump.	domestic and boiler.	Miocene; gravel and black sand.	Another horizon at 30-40 ft.
....	50±	....	....	Miocene; shell, sand and gravel.	Another horizon at 140 ft.
2	....	flows.	domestic.	Miocene; gravel.	Flow varies with tide. See analysis No. 35, table 2, pp. 506, 507. See U. S. G. S. Bull. 138, p. 198. Other horizons at 50 and 75 ft.
¾	....	pumped.	domestic.	Miocene.	Other horizons at 150 and 180 ft.
1	....	pumped.	domestic.	Miocene; gravel.	Another horizon at 30 ft.
....	....	pumped.	domestic.	Miocene; sand below shell-rock.	
....	....	hand pump.	domestic.	Miocene; from beneath rock.	Other horizons at 75 and 125 ft.
....	....	pitcher pump.	domestic.	Miocene; gravel.	See water assay No. 100, table 1, pp. 498, 499. Other horizons at 60 and 150 ft.
....	....	pitcher pump.	domestic.	Miocene; gravel.	Other horizons at 50 and 75 ft.
....	....	pitcher pump.	domestic.	Miocene; fine rock.	Another horizon at 140 ft.
10?	....	pitcher pump.	domestic.	Miocene; gravel, sand and rock.	
....	....	pump.	domestic.	Miocene; gravel.	
....	....	....	....	Miocene; blue sand and shells.	
....	....	hand pump.	drinking.	Miocene; sand.	
....	....	hand pump.	drinking.	Miocene; sand and pebbles.	
....	....	hand pump.	drinking.	Miocene; sand.	
....	....	....	....	Miocene; sand.	
....	15	pumped.	domestic.	Miocene; sand.	Another supply at 75 ft.
....	....	....	drinking.	Miocene; rock.	
....	....	....	....	Miocene; sand.	Another supply at 80 ft.
....	....	....	....	Miocene.	Set of samples with fossils received. See section, p. 252.
....	....	pumped.	domestic.	Miocene? sand and shells.	See water assay No. 99, table 1, pp. 498, 499.
....	....	pumped.	domestic.	Miocene? sand and shells.	
½	....	pumped.	domestic.	Miocene.	See analysis No. 35, table 2, pp. 506, 507

HYDE

Number.	Location.	Owner.	Date completed.	Elevation of surface above datum.	Datum.	Depth—feet.	Diameter—Inches.	Depth to principal water supply—feet.	Height of water, ± surface feet
27	Swanquarter	A. Berry	1904	2	sea level.	87	2	87	+0
28	do	S. S. Lupton	1890	5	sea level.	115	2	....	+2
29	do	Charles Brinn	1905	4	sea level.	120	2	....	−3
30	On Rose Bay Creek, 3 miles N. W. of Swanquarter.	W. R. Cutrell, Mason & Co.	1906	1½	sea level.	134	2	134	+0
31	Leechville, 1½ miles E. of	H. R. Russell	1902	6?	sea level.	156	2½	150-156	+2?
32	Makeleyville	M. Makeley, Edenton, N. C.	about 1879.	......	near sea level.	72	3	72	+0
33	Scranton	Alleghany Co.	......	......	near sea level.	123	3	123	+1½

JOHNSTON COUNTY.

Topography.—Portions of the southern and eastern parts of the county are covered by topographic maps. A reëntrant of the Wicomico terrace plain of the Pleistocene extends up Neuse River, having a width of several miles. Its elevations range from about 80 to 120 feet. The flat country around Smithfield forms a part of the Sunderland plain at elevations of from 130 to 150 feet. The Coharie plain covers a considerable area in the southern part of the county, at elevations of from 190 to 230 feet. This plain has been very much dissected. More than half of the county on its northwestern side presents a broken, hilly surface, with elevations ranging from 210 to 350 feet or more, the relief being of a Piedmont rather than of a Coastal Plain character.

Geology.—Basement rocks form the principal outcropping rocks in the northwestern half of the county, although these are mantled to greater or lesser extent with sands and gravels of the Lafayette and Coharie formations. Over the southeastern portion of the area the Patuxent formation, consisting of compact clays and gray, arkosic sands, underlies the region and rests upon the uneven, buried crystalline surface. These are overlain to a limited extent in the southeast by sands and clays of the Black Creek formation. The Patuxent and Black Creek beds are concealed by a surface covering of Pleistocene deposits consisting of sandy clays, sands, and gravels belonging to the Coharie, Sunderland, and Wicomico formations, or along their western border by Lafayette beds of similar character.

Water Resources.—Most of the inhabitants of this county obtain an abundant supply of water from shallow dug or driven wells 10 to 40 feet in depth. The water comes from the lower sandy and gravelly

COUNTY—CONTINUED.

Yield per minute. Flow—gallons.	Yield per minute. Pump—gallons.	How obtained at surface.	Use.	Geologic horizon and character of water-beds.	Remarks.
....	....	pitcher pump.	domestic.	Pliocene? coarse sand.	Water all way below 10 ft.
....	5	hand pump.	drinking.	Miocene? gravel.	
....	....	hand pump.	domestic.	Miocene.	
$3\frac{8}{10}$	....	flows.	boilers.	Miocene.	
....	....	flows.	drinking.	Miocene: brown sandstone.	Water all the way below surface.
....	....	....	boiler.	Miocene? sand.	
....	....	flows.	domestic and boiler.	Miocene; gravel.	Another horizon at 50 or 60 ft.

portions of the Pleistocene and Lafayette deposits. At many places in the northwestern half of the county the crystalline rocks either outcrop at the surface or are close to it, and a considerable number of the open wells are dug into them. Small springs occur along the slopes of the valleys and scarps. These springs are used for domestic purposes to a limited extent. Nearly all of the deeper wells of the county derive their supply from the underlying crystalline rocks. A partial list of these is given in the table of well data below.

At Smithfield a bluish slate or phyllite rock is struck at depths varying from 15 to 40 feet beneath the surface. Many wells ranging from 60 to 150 feet in depth have been drilled into this rock. Within the corporate limits over 20 deep wells obtain a supply from this source. Several mills near the town, but outside the corporate limits, also have drilled wells. The water from the slate rises to within 10 feet of the surface. In many cases it contains considerable iron. Only a few of the more typical wells are included in the table of well data.

At Selma a slate similar to that at Smithfield is struck at from 20 to 70 feet below the surface. Drilled wells are numerous. The wells range in depth from 140 to 300 feet, the average depth being about 160 feet. The water rises to within 15 feet of the surface, the amount obtainable varying considerably, in many cases the level being lowered several feet by pumping. The water is as a rule ferruginous and sulphurous. The drilled wells of the Southern Railway and the Atlantic Coast Line Railroad at Selma do not furnish sufficient water to supply their needs. The supply is added to by dug wells sunk around the casing of the drilled wells to the water-bearing sands at the base of the Pleistocene. The dug well at the tank of the former has a depth of 25

feet, a diameter at the top of 18 feet and at the bottom of 10 feet. At the tank of the latter the dug well has dimensions of 20 by 20 by 20 feet. The table contains only a partial list of the deep wells at Selma.

Several deep wells have been drilled at Kenly, the depths ranging from 90 to 160 feet. Bedrock is encountered at about 23 feet below the surface. The six wells of the Dennis Simmons Lumber Company, pumped together, are reported to yield 50 gallons per minute for an indefinite time and to show no lowering of the water level.

A flowing well about 40 feet deep is reported on low land about 2 miles south of Pine Level which probably derives its supply from the Patuxent beds. No other wells are known whose water comes from this source.

Assays and one analysis of waters from this county are given elsewhere in this report, as follows: Table 1, pp. 498, 499, assays Nos. 101-

JOHNSTON

Number.	Location.	Owner.	Date completed.	Elevation of surface above datum—feet.	Datum.	Depth—feet.	Diameter—inches.	Depth to principal water supply—feet.	Height of water, ± surface—feet.
1	Smithfield	Smithfield Cotton Mills	1901	about 150.	sea level.	150±	4		—16
2	....do	L. A. Munns	1906	about 150.	sea level.	63	2	60	—10
3	Smithfield, at Tuscan Hotel	Smithfield Improvement Co.	1906	about 150.	sea level.	125	12?		
4	Smithfield, cor. Third and Market.	Town	about 1901.	150	sea level.	106			—10
5	Smithfield, 5 miles W. of	W. B. Johnson	1898	about 200.	sea level.	149½	3	149½	—35
6	Selma	R. B. Covington & Co.	1906	175	sea level.	265?	8		
7	....do	N. E. Edgerton	1903	173	sea level.	168	5	160	— 7
8	....do	Selma Knitting Mills	1906	about 175.	sea level.	140	4½	140	— 4
9	....do	Southern Railway	1897	178	sea level.	208	10	200	— 6
10	....do	William D. Avera	1904	about 175.	sea level.	185	4		—18
11	....do	....do	1900	about 175.	sea level.	90	3		—18
12	....do	....do	1903	about 175.	sea level.	92	2½		—14
13	....do	....do	1900	about 175.	sea level.	70	3		—10
14	....do	A. C. L. R. R.		about 175.	sea level.	265	8		
15	....do	Town		about 175.	sea level.	165	6		
16	....do	Winston Cotton Gin		about 175.	sea level.	90?	4½		
17	....do	Lizzie Cotton Mills		about 175.	sea level.	307	8		
18	....do	W. D. Avera		about 175.	sea level.	300	2		
19	Selma, ½ mile S. of	Navassa Guano Co.	1904	about 175.	sea level.	238±	8	220	— 9

104; Table 2, pp. 506, 507, analysis No. 36. These are discussed on page 488.

Artesian Prospects.—Over the greater part of this county water is obtainable from wells drilled in basement slates or phyllites and associated rocks at depths ranging from 100 to 300 feet. The water from this source will in most cases rise within a few feet of the surface.

The only possible source of deep-well water in Coastal Plain materials is the Patuxent formation in the southeastern part of the county. The uneven character of the rock surface on which the Patuxent beds rest, however, renders the thickness present at any one place uncertain, but it is probable that it does not exceed 100 feet in many places. Flowing wells from this source are believed to be possible on the lowlands along Neuse River and its tributaries. The water carried by the Patuxent beds is probably everywhere of excellent character.

COUNTY.

Yield per minute.		How obtained at surface.	Use.	Geologic horizon and character of water-beds.	Remarks.
Flow—gallons.	Pump—gallons.				
....	....	steam pump.	boiler.	basement rocks.	Entered basement rock at 20 ft.
....	....	force pump.	domestic.	basement rocks.	Entered basement rock at 45 ft. Another horizon in Coastal Plain materials at 30 ft. See water assay No. 104, table 1, pp. 498, 499.
....	....	steam pump.	domestic.	basement rocks.	Entered basement rock at 60 ft.
....	....	force pump.	public.	basement rocks.	See water assay No. 102, table 1, pp. 498, 499. Entered basement rock at about 20 ft.
....	....	force pump.	domestic.	basement rocks.	Entered basement rock at about 55 ft.
....	....	windmill.	domestic.	basement rocks.	
....	....	force pump.	domestic.	basement rocks.	Entered basement rock at 26 ft. Lowered 10 ft. by pumping. Another horizon at 135 ft.
....	....	force pump.	boiler.	basement rocks.	Depth to basement rock, 30 ft. Lowered 13 ft. by pumping.
....	9	steam pump.	boiler.	basement rocks.	Entered basement rock at 30 ft.
....	50?	steam jet.	boiler.	basement rocks.	Entered basement rock at 30 ft.
....	....	....	....	basement rocks.	Entered basement rock at 20 ft.
....	....	....	....	basement rocks.	Entered basement rock at 30 ft.
....	....	....	....	basement rocks.	Entered basement rock at 20 ft.
....	....	....	....	basement rocks.	
....	....	....	....	basement rocks.	
....	....	....	....	basement rocks.	
....	....	....	....	basement rocks.	
....	....	....	....	basement rocks.	Entered basement rock at 70 ft. and no water obtained.
....	....	steam pump.	domestic and manufacturing.	basement rocks.	Entered basement rock at 20 ft. Lowered 9 ft. by pumping. Other horizons at 12, 116, 130 and 180 ft.

JOHNSTON

Number.	Location.	Owner.	Date completed.	Elevation of surface above datum—feet.	Datum.	Depth—feet.	Diameter—inches.	Depth to principal water supply—feet.	Height of water, + surface feet.
20	Selma, ½ mile W. of	Selma Cotton Mills	1904	about 175.	sea level.	168±	6?		—12
21	Pine Level	Town	about 1903.	160	sea level.	104±	4?	202	—10
22	....do	Pine Level Oil Mill		160	sea level.	101			—10
23	....do	Oliver, Godwin & Lynch		about 160.	sea level.	110			
24	Kenly	Town	1906	204	sea level.	100±	4?	70	—12±
25	....do	Dennis Simmons Lumber Co.		204	sea level.	162	6		

JONES COUNTY.

Topography.—Two Pleistocene terrace plains make up the surface of this county. The southeastern part of the county is covered by the Chowan plain, which varies in elevation from 25 to about 45 feet. The remainder of the area is covered by the Wicomico plain at elevations of from 50 to 80 feet. The latter is somewhat dissected by Trent River and its small tributaries, but there are broad interstream areas which are very flat. Great Dover Swamp and Whiteoak Pocoson form parts of this plain. The two terrace plains are separated by a scarp which in places is well defined.

Geology.—Peedee beds, consisting of marine sands and clays, underlie the entire county, having a limited area of outcrop in the extreme northwest, but coastward, passing deeper and deeper beneath overlying Eocene beds belonging to the Trent formation. In this northwest region the Peedee formation is in turn underlain at a considerable depth, perhaps 400 or 500 feet, by beds of the Black Creek formation. These pass deeper beneath the Peedee beds in the direction of the coast. The Trent beds are present over most of the county, becoming thicker to the southeast. They consist for the most part of porous, siliceous limestones, although there are interstratified sandy layers. At Pollocksville along Trent River the formation contains a great bed of oysters having a thickness of 12 to 15 feet, made up almost entirely of the species *Ostrea georgiana,* a massive form which often exceeds 12 inches in length. Miocene sands and shell marls, which probably exist as thin, disconnected sheets, rest upon the Eocene over at least parts of the county. A thin covering of sands, sandy loams, and clays of Pleistocene age, which belong in part to the Wicomico formation and

COUNTY—CONTINUED.

Yield per minute. Flow—gallons.	Yield per minute. Pump—gallons.	How obtained at surface.	Use.	Geologic horizon and character of water-beds.	Remarks.
....	50	steam pump.	drinking and boilers.	basement rocks.	Lowered 20 ft. by pumping.
....	....	hand pump.	....	basement rocks.	Entered basement rock at 37 ft.
....	50+	pump.	....	basement rocks.	Entered basement rock at 40 ft.
....	....	....	....	basement rocks.	Entered basement rock at 40 ft.
....	....	hand force pump.	domestic.	basement rocks.	Entered basement rock at 23 ft. Another horizon in Coastal Plain materials at 22 ft.
....	....	....	....	basement rocks.	Five other wells in area of ½ acre, with depths as follows: 90, 100, 100, 102, 104.

in part to the Chowan formation, spread over the older formations throughout the county.

Water Resources.—Until within the last few years the lower sandy portions of the Pleistocene formations have furnished a large part of the domestic water supply. At the present time, however, the porous Eocene limestone is tapped by a great many wells at depths varying from 7 to 153 feet, the most common depth being 30 or 40 feet. The water in this horizon is under but little pressure, with the result that flowing wells are almost unknown. The supply obtained at most places seems to be almost inexhaustible. Many springs issue from the limestone along the Trent River and its tributaries. Some of the deeper wells may penetrate Peedee beds which underlie the Eocene limestones. A flowing well is reported in the northwestern part of the county, but no data are obtainable regarding it. It is probable, however, that it taps a Peedee horizon. A few typical wells are included in the table given below.

At Trenton water is obtained from drilled wells 25 to 153 feet in depth. Only one driven and two open wells are reported in the town. The most common depth of the drilled wells is about 40 feet. The water comes from shell-rock and rises to within a few feet of the surface.

At Polloksville drilled wells are in most general use. Water is obtained from shell-rock at from 10 to 60 feet below the surface. The most common depth is from 25 to 35 feet. (See assay No. 107, pp. 498, 499.)

At Whitford, springs and open and drilled wells are used. The wells are from 20 to 40 feet deep. The water comes from shell-rock.

At Maysville it is about 40 feet to the shell-rock. The open wells average 15 feet in depth, the driven wells 15 to 18 feet, and the drilled

wells 50 feet. The deepest drilled well is 68 feet deep. In the drilled wells water rises to within 2 to 8 feet of the surface. The shallow water is reported unsatisfactory.

At Comfort a few dug wells are used, and only one or two driven wells. A few drilled wells 25 to 87 feet in depth are in use. The water rises to within 10 feet of the surface. It is found in shell-rock.

In the northwestern part of the county, in Chinquapin Township, drilled wells are owned by nearly every family. The wells average 30 feet in depth, but range all the way from 7 to 70 feet. The water, which is obtained from shell-rock, rises to within 2 to 10 feet of the surface.

Assays of waters from this county are given in Table 1, pp. 498, 499, assays Nos. 105-108. These are discussed on page 488.

JONES

Number.	Location.	Owner.	Date completed.	Elevation of surface above datum—feet.	Datum.	Depth—feet.	Diameter—inches.	Depth to principal water supply—feet.	Height of water, ± surface—feet.
1	Comfort	C. A. Rhodes	1906	51	sea level.	80	1½	80	—10
2	....do	Goldsboro Lumber Co.	1904	50	sea level.	87	3	87	—10
3	Tuckahoe	E. M. Jarman	......	......	....	62	1¼	....	+ 0
4	Trenton	G. T. Coble	1904	30	sea level.	133	1¼	....	—12
5	....do	Mrs. V. Perry	1904	30	sea level.	123	1½	....	— 5
6	....do	L. F. Andrews	1893	44	sea level.	21	1½	21	—10
7	....do	J. C. Parker	......	35±	sea level.	153	1¼	....	......
8	Whitford, 1 mile S. of	M. J. Green	1899	25±	sea level.	37	2	37	......
9	....do	M. D. Frazell	1906	25±	sea level.	35	2	30	—25?
10	Whitford, 2 miles E. of	W. F. Foy	1893	21	sea level.	40	1¼	39½	— 8

LENOIR COUNTY.

Topography.—Three Pleistocene terrace plains form the surface of this county. Neuse River is bordered by the Chowan plain, which has a width of several miles and elevations probably ranging between 30 and 60 feet. This is separated from the next higher or Wicomico plain almost everywhere by a well-defined scarp. The latter plain is believed to cover the greater part of the county at elevations of from 50 to perhaps 70 feet, although the lack of topographic maps renders its extent and elevation somewhat uncertain. It is believed that the next higher or Sunderland terrace plain at elevations exceeding 100 feet covers a small area in the extreme northwest, the town of LaGrange being situated upon it.

Artesian Prospects.—The Eocene beds and the underlying Peedee beds are the only artesian water horizons which have thus far been explored by deep drilling. In neither is the head sufficient to produce flowing wells, except possibly in the very lowest places along the streams. The water, however, always rises within reach of suction pumps. In the southeastern part of the county wells drilled through the Eocene beds into the underlying Peedee beds, which in this region must be several hundred feet beneath the surface, would, it is believed, encounter salty water.

In the central and western parts of the county deeper drilling to depths of 400 or 500 feet or more would probably reach horizons in the Black Creek formation which would yield abundant supplies of potable water, although the water might prove to be brackish.

COUNTY.

Yield per minute.		How obtained at surface.	Use.	Geologic horizon and character of water-beds.	Remarks.
Flow—gallons.	Pump—gallons.				
		hand pump.	domestic.	Trent formation; rock.	Other horizons at 40 and 60 ft.
		pitcher pump.	domestic.	Trent formation; sand.	
		flows.		Peedee formation?	
		force pump.	domestic.	Trent formation.	
		hand pump.	domestic.	Trent formation.	
		hand pump.	domestic.	Trent formation.	Entered Eocene rock at 18 ft.
				Trent formation.	
		hand pump.	domestic.	Trent formation.	Entered Eocene rock at 30 ft. Other horizons at 25 and 32 ft.
		hand pump.	domestic.	Trent formation; sand.	Other horizons at 22 and 30 ft.
		hand pump.	domestic.	Trent formation; sand.	Entered Eocene rock at 23½ ft. Another horizon at 23 ft.

Geology.—With the exception of a small area in the northwest, the entire county is underlain by the Peedee formation, which here consists of dark greenish or grayish, glauconitic sands and clays, with occasional indurated layers. The Peedee formation is underlain conformably by the Black Creek formation, which appears above water level in a small area in the northwestern part of the county. Miocene sands and clays are probably present in the northeast, resting unconformably upon the Peedee beds. A thin covering of Pleistocene sandy clays, sands, and gravels belonging to the Sunderland, Wicomico, and Chowan formations overlies all earlier formations.

Water Resources.—An abundant supply of water is obtainable by means of shallow open and driven wells in the lower sandy water-

bearing portions of the Pleistocene deposits. These wells range from 10 to 20 feet in depth. A few reach to 30 feet, but in these the water probably comes from the sandy portions of the underlying Peedee beds.

Numerous small springs occur along the valley and scarp slopes. emerging from the base of the Pleistocene deposits. The principal sources of the deeper well waters of the county are the Cretaceous beds of the Peedee and Black Creek formations.

Wells concerning which information has been obtained are included in the tables of well data below. (See also Bull. U. S. Geol. Survey, No. 138, pp. 203-204.)

Kinston is situated on the Chowan terrace which borders Neuse River. The city owns its water system, the supply being derived from 3 wells each 310 feet deep. The water is raised by an air lift and overflows into a circular cement reservoir of 350,000 gallons capacity, sunk in the terrace close to the pumping station. Two of the wells are situated within the reservoir, while the third well is 40 feet off to one side. From the reservoir the water is raised by a McGowan steam pump to a standpipe of 150,000 gallons capacity situated on the higher land north of the city. In case of fire it is possible to pump directly into the city mains. The wells are situated three-fourths of a mile west of the city post-office and about 200 yards from Neuse River. The maximum capacity of each well is stated to be 150 gallons per minute. The three wells are usually pumped together at the rate of 300 gallons per minute. There are about 12 miles of water mains laid in Kinston and about one-fourth of the inhabitants are supplied, approximately 120,000 gallons being used daily. The system was established in 1905, the wells being completed that year. The water supplied by these three wells is probably derived from sandy layers in the Black Creek formation. A water-bearing stratum, between 88 and 104 feet below the surface. yielded by pumping 150 gallons per minute of extremely hard water. The water from this horizon did not overflow. At a depth of 212 to 220 feet another water-bearing horizon was encountered from which soft water, very similar to that obtained at 304 feet, could be pumped at the rate of 45 gallons per minute. This water would flow at the rate of 15 gallons per minute. A horizon which furnishes the main part of the supply was encountered at 304 feet; this flows at the rate of 15 gallons per minute. The water from this horizon will rise 24 feet above the surface. Pumping at the rate of 150 gallons per minute on one well lowers the water level to a point 150 feet below the surface.

Several wells in the vicinity of Kinston tap a horizon at 210 feet,

which yields strong flows. The county well at Kinston, which is 225 feet deep, has a flow of 10 gallons per minute. The water from this horizon is soft.

Mr. H. H. Carr, who has drilled a large number of wells in the vicinity of Kinston, has furnished the following table of records:

RECORD OF WELLS DRILLED AT KINSTON AND VICINITY
BY H. H. CARR, GOLDSBORO, N. C.

WELL No.	OWNER.	DEPTH No. FEET.
1	S. H. Isler, Jr.	240
2	E. M. Hodges Machine Works	230
3	Lenoir Oil and Ice Company	225
4	Hines Bros. Lumber Company	225
5	W. H. Ashley Silk Company	220
XX 6	E. P. Loftin, R. F. D. No. 4	538
· 7	County of Lenoir	225
8	Kinston Cotton Mills	225
9	J. P. Taylor, President	276
10	J. P. Taylor, President	276
11	J. P. Taylor, President	225
12	Orion Knitting Mills	225
X 13	J. Hyman Newborn	400
X 15	Hines Bros. Lumber Co.	370
16	J. F. Nobles	240
17	Caswell Cotton Mills	220
18	City of Kinston	225
19	City of Kinston	220
20	City of Kinston	220
21	City of Kinston	220
22	B. F. Fields	200
23	J. F. Horner	200
X 24	L. Harvey	325
25	Robert Hodges	145
26	Robert Hodges	145
XX 27	Paul A. Hodges	470

Wells marked XX afforded no water at all.

Wells marked X afford an abundance of water, but do not flow.

Well No. 10 is 7 inches in diameter. It affords flows at depths of 224 feet and 276 feet respectively.

All not specially marked are flowing wells, varying in quantity from 5 to 30 gallons per minute through 2-inch pipes.

A few deep wells have been drilled at LaGrange. One recently drilled for the town authorities was located just south of the railroad on the main street. The total depth reached in this well was said to have been about 280 feet. It was started with a 6-inch pipe and later a 4-inch pipe was used within the larger. The materials passed through are reported to have been sand from top to bottom, with occasional thin strata of clay. The material from the bottom of the well was a clean, gray, micaceous, slightly glauconitic sand. Plenty of water was encountered, but because no overflow was obtained and because quicksand hindered the drilling, work was discontinued and the well abandoned. The water rose to within 25 feet of the surface. The elevation of the surface here, which is 109 feet above sea level, is too great to permit of flowing wells.

On the Chowan terrace bordering Neuse River, south and southeast

LENOIR

Number.	Location.	Owner.	Date completed.	Elevation of surface above datum—feet.	Datum.	Depth—feet.	Diameter—inches.	Depth to principal water supply—feet.	Height of water, ± surface—feet.
1	Kinston	City	1904	44	sea level.	310	8	304	— 0
2	...do	Hines Bros. Lumber Co.	1907	about 45.	sea level.	210	3		+ 3
3	...do	County	1907	about 45.	sea level.	225	2½		+ 0
4	Kinston, 1 mile E. of	S. W. Isler	1906	38	sea level.	248	2		+ 2
5	Kinston, 6 miles S. W. of	W. E. Sutton	1906			200	1½	200	+ 2
6	Kinston, 4 miles S. of	Mrs. Helen Kennedy	1891			150±			—10?
7	Kinston, 5½ miles S. W. of	Jesse Jackson	1906	50±	sea level.	228	1½	216	+ 2
8	LaGrange	E. M. Flowers		about 100.	sea level.	175	1½		
9	LaGrange, 6 miles S. E. of	W. F. Sutton	1906	40±	sea level.	100	1½		+ 0
10	LaGrange, 4 miles E. of	F. R. Hodges	1904	40±	sea level.	96	1½		+ 4
11	LaGrange, ½ mile S. of	A. Miller	1906	75	sea level.	100	1½		—10
12	LaGrange, 5 miles S. of	Ira Dawson	1897	40±	sea level.	56	2½		+ 6
13	LaGrange, 5 miles S. of	Mrs. Delia Dawson	1895	40±	sea level.	67	3		+ 4
14	Falling Creek	Joshua Dawson		40±	sea level.	115	1½		+ 6
15	Falling Creek, 2 miles S. E. of.	William Herron		40±	sea level.	158			+ 0
16	Falling Creek, 3 miles S. E. of.	J. H. Darden	1906	40±		152	1½	152	+ 8
17	Falling Creek, 1½ miles S. of	W. L. Kennedy	1906	40±		140	1½	140	+ 4
18	Pinkhill	J. J. Smith	1906			190	1½		

of LaGrange, as far as Falling Creek Station on the Norfolk Southern Railroad, there are many flowing wells ranging in depth from 57 to 158 feet. The amount of flow varies from 5 to 25 gallons per minute. The first flowing well in the Falling Creek region was drilled about the year 1889. The horizon tapped was at a depth of 60 feet. The water in some of these wells is slightly sulphurous. In wells near Falling Creek Station the water will rise about 6 to 15 feet above the surface.

Assays and analyses of waters from this county are given elsewhere in this report, as follows: Table 1, pp. 498, 499, assays Nos. 109-113; Table 2, pp. 506, 507, analyses Nos. 37, 38. These are discussed on page 488.

Artesian Prospects.—Abundant supplies of potable water are obtainable from the sand strata of the Peedee and Black Creek formations, particularly the latter, which underlie the whole county. Flows are possible on the Chowan terrace plain bordering Neuse River and on the lowlands along the tributaries of the Neuse.

COUNTY.

Yield per minute.		How obtained at surface.	Use.	Geologic horizon and character of water-beds.	Remarks.
Flow—gallons.	Pump—gallons.				
15	150	air lift.	city supply.	Black Creek formation; sand.	Other supplies at 88-104 and 212-220 ft. See analysis No. 38, table 2, pp. 506, 507. See Sec. Bull. U. S. G. S. 298, pp. 245-246. There are three similar wells used.
10	....	....	....	Black Creek formation; sand.	
10	....	....	....	Black Creek formation; sand.	
19	....	flows.	domestic.	Black Creek formation; sand.	
3	....	flows.	drinking.	Black Creek formation; sand.	
....	....	pitcher pump.	domestic.	Peedee formation?	
2	....	flows.	domestic.	Black Creek formation.	Decrease from 6 to 2 gals. per minute. See water assay No. 110, table 1, pp. 498, 499.
....	....	suction pump.	....	Black Creek formation?	
23	....	flows.	domestic.	Black Creek formation; sand.	
10	....	flows.	domestic.	Black Creek formation; sand.	Another supply at 25 ft. Three other similar flowing wells. See water assay No. 113, table 1, pp. 498, 499.
....	....	pump.	domestic.	Black Creek formation; sand.	
12½	....	flows.	....	Black Creek formation; sand.	
16	....	flows.	....	Black Creek formation; sand.	
5	....	flows.	domestic.	Black Creek formation; micaceous sand.	
12	....	flows.	domestic.	Black Creek formation.	
11	....	flows.	domestic.	Black Creek formation; sand.	
25	....	flows.	domestic.	Black Creek formation; sand.	
....	....	....	not used.	....	No water obtained.

MARTIN COUNTY.

Topography.—Two Pleistocene terrace plains form the surface over the greater part of this county. The Chowan plain covers much of the area east of Sweetwater Creek which enters Roanoke River near Williamston; its elevations range from about 30 to about 40 feet. The Wicomico plain spreads over all the area to the west of Sweetwater Creek at elevations ranging from 60 to 90 feet. The two terraces are separated by a well-defined sea-facing scarp. Both are somewhat dissected by stream erosion. The Pamlico plain, the youngest and lowest of the Pleistocene terraces, has a limited development along Roanoke River.

Geology.—Miocene deposits consisting of beds of greenish or gray sands, bluish-drab clays, and shell marls underlie the entire county beneath a thin covering of Pleistocene terrace deposits. In the extreme western part of the county the compact sands and clays of the Patuxent formation underlie the Miocene at depths of about 80 to 100 feet. These pass coastward unconformably beneath the Miocene, becoming deeper. In the eastern two-thirds of the county it is probable that beds of the Cretaceous Black Creek and Peedee formations intervene between the Patuxent and Miocene beds at depths of several hundred feet beneath the surface. The Patuxent beds rest upon basement rocks which are estimated to lie at a depth of 600 feet below the surface in the western part of the county, and at about 1,400 feet in the eastern part.

Water Resources.—The inhabitants of this county obtain an abundant supply of water for domestic use from shallow open and driven

MARTIN

Number.	Location.	Owner.	Date completed.	Elevation of surface above datum—feet.	Datum.	Depth—feet.	Diameter—inches.	Depth to principal water supply—feet.	Height of water, + surface feet.
1	Robersonville	R. H. Hargrove and R. J. Nelson.	1906	60	sea level.	175	2	175	—14
2	Everetts	G. P. McNaughton	1906	60	sea level.	200	2	200	—18
3	Jamesville	Jamesville	1903	.....	.....	280	4?	280	—10

MOORE COUNTY.

Topography.—The surface of this county is made up of rolling hills. The southeastern portion comes within the well-known sandhill belt with maximum elevations probably exceeding 500 feet. The remainder is within the Piedmont region and presents a relief peculiar to that region.

wells 10 to 20 feet deep. A few of the wells are driven as deep as 30 or 40 feet. The water comes from the lower sandy portions of the Pleistocene formations and from the upper sandy beds of the Miocene. At Parmele all the shallow well water is ferruginous. At Williamston three large open wells, approximately 8 or 10 feet square and 10 or 12 feet deep, furnish an abundance of water for fire protection. At Goldpoint and Robersonville a few families obtain water from springs.

Few deep wells have been drilled in the county. The reader is referred to the table of well data for information concerning such as have been reported.

One assay of a water from this county is given in Table 1, pp. 498, 499, assay No. 114. This is discussed on page 489.

Artesian Prospects.—The sandy beds of the Miocene should be water-bearing in all parts of the county, although the few attempts to obtain supplies from this source have not thus far been very successful. In the extreme west excellent water should be obtained from the Patuxent formation at depths exceeding 100 feet. As these beds pass to greater depths eastward, their water content probably becomes somewhat mineralized. The wells at Everetts and Robersonville probably derive their supply from this source. In the eastern two-thirds of the county, where the Black Creek and Peedee beds are believed to intervene between the Patuxent and Miocene, these, if present, should furnish potable waters.

Flowing wells are believed to be possible in the lowlands bordering Roanoke River and its tributaries, but not at the higher terrace levels.

COUNTY.

Yield per minute. Flow—gallons.	Yield per minute. Pump—gallons.	How obtained at surface.	Use.	Geologic horizon and character of water-beds.	Remarks.
....	....	windmill.	domestic.	Patuxent formation? white sand.	Another horizon at 15-40 ft.
....	small.	air compressor.	not enough to use.	Patuxent formation; coarse white micaceous sand.	
....	....	force pump.	domestic.	Miocene; gravel and sand.	

Geology.—The northwestern half of the county lies within the Piedmont province, although remnants of sands or gravels of the Lafayette may flank or cap some of the hills. Deposits of the Coastal Plain cover the southeastern half of the county, but these rest upon basement rocks whose uneven surface lies at varying, though comparatively shallow, depths beneath the surface. The Coastal Plain materials consist

principally of gray, arkosic, cross-bedded sands and drab clays of the Patuxent formation, although there is a comparatively thin covering of sands and gravels of the Lafayette capping the hills and mantling down over their slopes.

Water Resources.—Over the Coastal Plain portion of the county water for domestic purposes is obtained principally from open dug wells 10 to 60 feet in depth. A few driven wells are in use. The source is in part the sands and gravels of the Lafayette formation, and in part the sands of the underlying Patuxent formation. Springs are abundant, and where convenient to dwellings are used for domestic purposes.

At Pinehurst, previous to 1905, the hotels at that place were furnished with water by means of a steam pumping plant situated near the head of a little valley near the hotel buildings. A group of 16 wells 20 to 45 feet in depth were used, the supply coming from Patuxent beds. Analyses showed that several of these wells had become polluted from surface sources, and it became necessary to look elsewhere for a supply. A deep well was drilled near the plant. An 8-inch pipe was sunk through the Coastal Plain materials (Patuxent formation) to the surface of the basement crystalline rocks at a depth of 197 feet, and drilling was continued in the rock to a depth of 730 feet. An abundant supply of water was obtained which was said to come from a crevice in the rock. It was claimed that no good supply was encountered in the Coastal Plain materials above the rock surface.

At Aberdeen there are a number of wells on the hill slopes ranging in depth from 50 to 70 feet and in the valley ranging from 20 to 30 feet. The supply is amply sufficient for domestic purposes.

A waterworks system was established at Pinebluff in 1901. The source of supply is a spring from which the water is pumped to a 20,000-gallon tank on the top of a 50-foot tower located on a nearby hill. The pump has a capacity of 30 gallons per minute. The plant is owned by R. B. Brown. Wells ranging in depth from 30 to 60 feet are in common use at Pinebluff, and the water is said to be satisfactory. There are many springs in the vicinity, some of which are used.

At Southern Pines there is a waterworks system owned by the town. The supply is obtained from 10 wells, each about 45 feet in depth, located on ground 50 feet lower than the Seaboard Air Line Railway track at the station. The water rises within 17 feet of the surface. It is pumped to a 60,000-gallon tank located on a hill 90 feet above the level at the railway station. The top of the tank is 80 feet above the surface of the ground. A good pressure is thus obtained. The water horizon here is in the Patuxent formation. Wells have been drilled

in other parts of the town and vicinity, concerning which little information has been obtained. Owing to the fact that a rather deep, narrow valley lies just to the west of the town, the water table lies low and but little artesian pressure is developed; it is necessary to use buckets or force pumps to bring the water to the surface.

Assays and one analysis of waters from this county are given elsewhere in this report, as follows: Table 1, pp. 498, 499, assays Nos. 115, 116; Table 2, pp. 506, 507, analysis No. 39. These are discussed on page 489.

Artesian Prospects.—The Patuxent formation offers the only source of deep-well water from the deposits of the Coastal Plain, and this only in the southeastern part of the county. The water may be expected to be soft and of excellent quality unless the well is located in close proximity to some source of surface pollution. Owing to the rolling and hilly character of the surface, the level of the water table is likely to be low in the hills, and therefore the water as a rule will not rise very near the surface in the case of wells located on high ground. It is possible that wells located on low ground in some of the deeper valleys might furnish flows.

The basement rocks underlying the deposits of the Coastal Plain may be looked upon as a possible source of supply.

NASH COUNTY.

Topography.—The Sunderland terrace plain of the Pleistocene, with elevations of 120 to 150 feet, forms the surface along the eastern border of the county, with reëntrants extending for some distance up the streams. A small area of the next lower or Wicomico plain is present bordering Tar River on its north side below the Upper Falls at Rocky Mount, having an elevation of about 100 feet. The Coharie plain at elevations of 190 to 230 feet covers a belt several miles wide, running northeast and southwest to the west of that covered by the Sunderland plain. To the west of the Coharie belt the surface is hilly, the topographic features resembling those of the Piedmont region rather than those of the Coastal Plain.

Geology.—Basement rocks, consisting of slates, schists, and granites, occur at or near the surface over the greater part of the county. About the western two-thirds of the county is covered to greater or lesser extent by surficial deposits of sandy clays, sands, and gravels belonging to the Lafayette formation and to the Coharie formation, which rest directly upon basement crystalline rocks. Along the eastern border the crystalline surface passes beneath overlapping Miocene beds. The latter are covered by Pleistocene terrace deposits consisting of coarse

sands and gravels which in places probably overlap upon the basement rocks. These belong to the Sunderland formation and to a very limited extent to the Wicomico formation.

Water Resources.—In the central and western parts of the county open wells 15 to 70 feet deep yield a supply of soft water which comes from the Lafayette and Coharie sands and gravels or from the porous, decomposed portions of the underlying crystallines. Along the eastern border of the county, where the deposits of the Sunderland formation form the surface, open and driven wells furnish an abundant supply at depths of from 10 to 30 feet. A few springs are used in the hilly portions of the county.

Rocky Mount, which lies partly in Nash and partly in Edgecombe County, has a public water system. The original system which derived its supply from a small stream known as Stony Creek, 4 miles northwest of the city, was installed in 1898. At present (spring of 1909) a new pumping station is being erected on the east bank of Tar River just west of the city. The following information concerning this new plant has been furnished by Mr. A. S. Lyon, Superintendent of Public Works: The pumping capacity is to be 4,000,000 gallons per day, which is to be effected by means of three pumps, one of 2,500,000 gallons capacity, and the other two of 750,000 gallons capacity each. The plant includes a coagulating basin of 200,000 gallons capacity, a clear-water basin of 500,000 gallons capacity, and a pressure filter of 2,000,000 gallons capacity, made by the New York Continental Jewel Filtration Company. The standpipe has a capacity of 150,000 gallons. The maximum standpipe pressure is 47 pounds, and the possible direct pressure ranges from 100 to 150 pounds on the different parts of the main. The number of miles of mains will be 14.2 and the number of fire hydrants 92. The water will be used for all domestic purposes and by manufacturing plants and railroads for steaming purposes. The old plant is being abandoned because its capacity for meeting the demand made upon it is no longer adequate.

Assays of waters from this county are given in Table 1, pp. 498, 499, assays Nos. 117, 118. These are discussed on page 489.

Artesian Prospects.—The Miocene beds along the eastern border of the county attain no great thickness and are not very important as an artesian source, although potable water may be expected from them. The underlying basement rocks may be regarded as a possible, though not very promising, source of artesian supplies.

NEW HANOVER COUNTY.

Topography.—No topographic maps have been made covering areas within the limits of this county, and but little data indicating eleva-

tions are available. The surface is formed of Pleistocene terrace plains, and from such information as can be secured the greater part of the surface is believed to lie within the limits of the Chowan plain, with elevations ranging from about 30 to about 50 feet above sea level. Limited areas of the Pamlico terrace plain not exceeding 20 or 25 feet above the sea are present along the coast and along Cape Fear and Northeast Cape Fear rivers. It is possible that the Wicomico plain, with elevations of 60 to 70 feet, extends into the county from the northeast. The surface has been somewhat dissected by stream erosion. Portions of the surface are covered with low, rolling sandhills. These are believed to constitute beach-sand accumulations which were deposited by the retiring sea at the time the Chowan plain, due to an uplift of the land, was emerging from the sea. These sand accumulations were doubtless shifted by the wind to form dunes in the same manner that such dunes are being formed at the present time in many places along the coast.

At a distance of about 1½ miles from the mainland the coast, beginning at its northeastern extremity and extending to Carolina Beach, is paralleled by a series of beaches and banks separated by narrow inlets. The sounds between these banks and the shore are being rapidly filled with detritus from the land.

Geology.—The deposits of this county rest upon a deeply buried surface of crystalline rocks. In the northern part of the county this surface is believed to exist at a depth of about 900 or 950 feet below sea level. At Wilmington it was encountered at 1,100 feet below sea level, and at Fort Caswell, in Brunswick County, which is near the southern extremity of New Hanover County, at about 1,530 feet below the same datum.

The relative positions and thickness of the materials of different ages making up the overlying formations are shown in the graphic section, Fig. 20, which is constructed along a line running lengthwise of the county from Castle Hayne to the southern extremity of the mainland. The lower 400 feet consist of marine materials of Cretaceous age, probably referable to the Black Creek formation. Above this comes a (maximum) thickness of 886 feet of gray or greenish-gray, more or less calcareous and glauconitic sands and marine clays belonging to the Peedee formation. In that part of the section between Castle Hayne and Wilmington the Peedee beds rise about to sea level, their upper surface undulating a little above and a little below this level. Near Wilmington their surface passes below sea level, gradually becoming deeper until near the southern extremity of the mainland of the county its

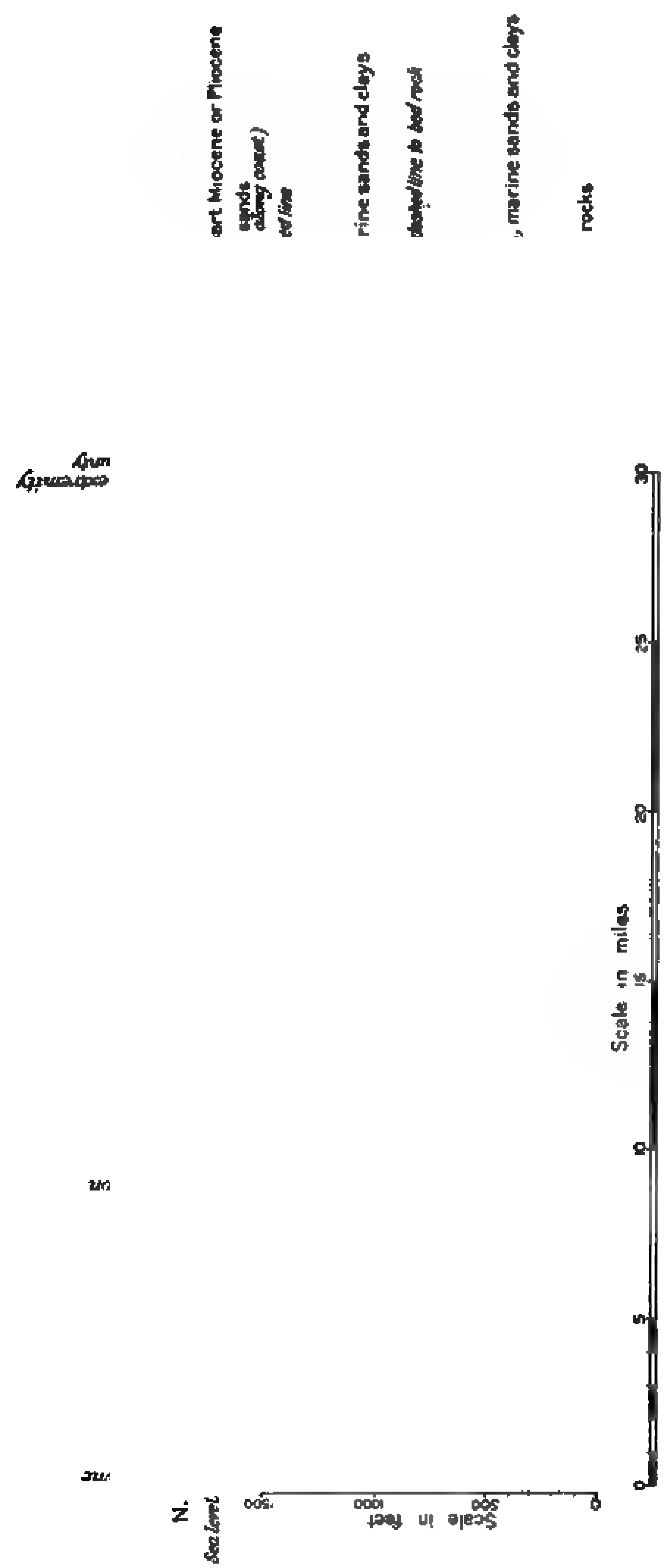

FIG. 20.—Geologic section across New Hanover County from Castle Hayne to southern extremity of county

depth below sea level is about 260 feet. The thickness at Wilmington of these undoubted Peedee beds, as shown by the record of the deep well at Hilton Park, is 720 feet.

Resting unconformably upon the undulating surface of the Peedee formation are the shell limestones and calcareous sands of the Castle Hayne formation of the Eocene. In the region between Castle Hayne and Wilmington these exist as shallow basin fillings upon the Peedee surface, the several basins probably being more or less separated from each other. South of Wilmington, where the Peedee surface passes below sea level, the Eocene beds, possibly representing both the Castle Hayne and Trent formations, thicken gradually until near the southern extremity of the mainland the thickness amounts to about 300 feet. They also thicken to the east of Wilmington, as indicated in the section from Wilmington to Wrightsville Beach. (Fig. 21.)

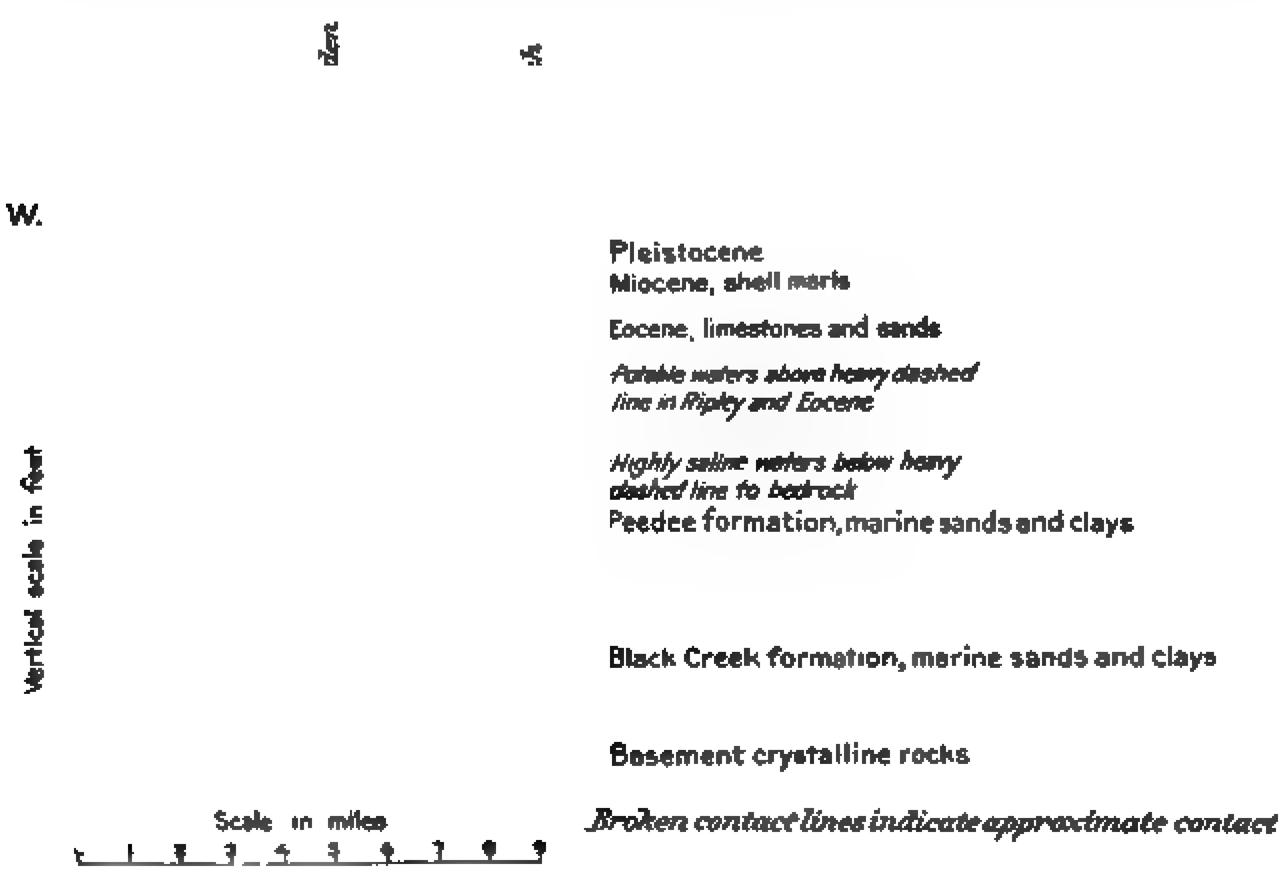

FIG. 21.—Geologic section across New Hanover County from Wilmington to Wrightsville Beach, N. C.

In the vicinity of Wilmington, Miocene shell marls rest upon the Castle Hayne limestone, but these seem to be present merely as disconnected sheets a few feet in thickness. But little is known of their distribution over the remainder of the county. Over the surface of all the county there is spread a surficial covering of Pleistocene terrace deposits, belonging for the most part to the Chowan formation, but in part to the Pamlico formation, and possibly in part to the Wicomico formation.

Water Resources.—An abundant supply of water for domestic use may be obtained at many places from the basal sandy beds of the Pleistocene deposits at depths of from 10 to 30 feet. Near dwellings, and especially in a city as large as Wilmington, such supplies are constantly liable to pollution from accumulations of various kinds of decaying matter on the surface, and should not, therefore, be used for domestic purposes when other purer supplies are available.

The waterworks plant at Wilmington is owned by the Clarendon Waterworks Company. The supply is taken from Northeast Cape Fear River at Hilton Park. The water here has a dark, yellowish-brown color, due to its organic content, and it also carries considerable solid matter in suspension. During periods of protracted dry weather, when the amount of fresh water in the river is small, or during times when strong winds from the south or southwest prevail for several consecutive days, brackish water finds its way up the Cape Fear estuary as far as the intake at the waterworks. This condition is of rare occurrence.

The dark color and the large amount of suspended matter present render the water in its natural state very unsatisfactory for the various domestic purposes, and for many years there was constant and just complaint as to the quality of the water supplied to the patrons of the water company. In response to the public demand for better water, a filtration plant was installed in 1907 which is designed to remove the suspended matter and by chemical treatment to remove the coloring matter. The water is pumped to a concrete sedimentation reservoir, from which it passes by gravity to the filters proper. In its passage through the filters, in addition to mechanical filtration, it is treated chemically with sulphate of alumina and soda ash. By the chemical treatment the color which in the original water ranged from 140 to 270 parts per million is reduced to from 20 to 50 parts. After filtration the water is pumped to a nearby standpipe for distribution. The plant has a normal capacity of 2,000,000 gallons and a maximum capacity of 2,600,000 gallons per day. As to its efficiency the consulting engineer of the company, Mr. George C. Whipple, has pronounced the plant a success. The State Board of Health has made monthly examinations of the filtered water and has pronounced it very potable.

The pumping station is equipped with 4 pumps having capacities respectively of 2,500,000, 2,000,000, 1,500,000, and 750,000 gallons per day. The standpipe, which is located near the plant, has a capacity of 211,000 gallons. It furnishes a pressure of 50 pounds per square inch. By pumping directly into the mains the pressure can be raised to 115 pounds. There are 16½ miles of water mains. For the various do-

mestic, sanitary, and manufacturing purposes these have been tapped at 2,170 places. The estimated consumption for manufacturing purposes is 3 per cent of the total amount of the water used. There are 131 fire plugs.

In recent years, and particularly within the last 8 or 10 years, a large number of deep wells have been drilled within the county limits, and especially within the limits of the city of Wilmington. Detailed information concerning a considerable number of these wells is included in the table of well data given below. The artesian supplies are derived from the more porous sandy strata of the Peedee formation, and along the coast from sand layers within the Eocene limestones. The artesian waters may be divided into two major classes: first, those that are highly mineralized and that are so salty as to be nonpotable and undesirable for ordinary purposes, and, second, those whose mineral content is sufficiently low to permit of their use for domestic and manufacturing purposes. The reader is referred to the sections (pp. 438, 439) where the approximate line of separation between these two classes of waters is indicated by dotted lines.

All horizons occurring beneath the dotted lines furnish water of a highly saline character, and cannot be regarded as satisfactory sources of artesian supply. In the deep well of the Clarendon Waterworks Company at Hilton Park, Wilmington, water with a salty taste, which flowed at the surface, was first encountered at a depth of 379 feet, and at a number of other horizons beneath this, almost to bedrock, salty flows were obtained. (See account of this well by J. A. Holmes, Science, new ser., vol. 2, 1900, pp. 128-130, and Journal Elisha Mitchell Sci. Soc., July-Dec., 1899, pp. 67-70. Also, see table of well data below. See Plate XLII, A, opposite p. 480.) At Castle Hayne, in a well drilled by the Carolina Trucking Development Company, nonflowing, salty waters were encountered in the Peedee formation from 270 to 338 feet and similar flowing, salty waters from 338 to 370 feet below the surface. At Fort Caswell, Brunswick County, which is but a few miles from the southern extremity of New Hanover County, salty water was encountered at 365 feet, and none but highly saline waters were obtained below this depth to bedrock at 1,540 feet. (See Brunswick County, page 372.)

Above the dotted lines in the sections referred to, the waters are in most places potable. They are usually slightly hard and in some cases are rather high in mineral content.

At Wilmington the principal water horizon is in the Peedee formation at depths of between 30 and 75 feet below *sea level.* The water comes from soft sand layers which alternate with layers of calcareous sandstone. The water rises but a few feet above sea level, and force

pumps are required to bring it to the surface. The supply from this source seems to be very abundant. At the Wilmington Steam Laundry, owned by J. T. Harper, this water is used for laundry purposes without special treatment. A considerable number of wells have been drilled to this horizon in various parts of the city, a partial list of which is included in the table below. Reports seem to show that the water is in the main satisfactory for domestic and for most manufacturing purposes. In the opinion of the writers, the horizon, if properly developed, could be used as a source of city supply.

At the Delgado Cotton Mills, 1 mile east of Wilmington, a Peedee horizon is tapped by 10 or 12 wells at depths of 90 to 100 feet. Water of good quality is obtained.

At Winter Park Garden, 3 miles east of the city, there are several wells which pass through Eocene beds and enter the Peedee beneath, but it is not certain whether the principal horizon is in the former or the latter. The water obtained is rather hard and ferruginous. Several flowing wells furnishing water of very satisfactory character have been drilled near Greenville Sound, and samples of the materials were obtained from one of them. (See section, p. 193.) The depth of the latter was 170 feet and the beds passed through, from 35 feet below the surface to the bottom, appear to belong to the Eocene. Along the coast, therefore, the Eocene appears to contain water-bearing beds.

A flowing well at Masonboro Sound is believed to have passed through the Eocene beds and to have entered the upper part of the Peedee formation. (See section, p. 168.) Water of satisfactory quality was obtained.

The 390-foot well of Mrs. Croft near Wrightsville undoubtedly enters Peedee beds, but the principal water horizon is believed to be in the Eocene at a depth of about 85 feet. This water is of good quality.

Good water is obtained at Wrightsville Beach from two wells 195

NEW HANOVER

Number.	Location.	Owner.	Date completed.	Elevation of surface above datum feet.	Datum.	Depth feet.	Diameter inches.	Depth to principal water supply feet.	Height of water, + surface feet.
1	Wilmington, Hilton Park..	Clarendon Waterworks Co..	1899	9	sea level.	1,330	6 at bottom.	......	+ 2
2	Wilmington, cor. Nunn and Third streets.	J. D. Bellamy, Jr......	1903	about 40.	sea level.	115	2	115	−40?

and 198 feet deep, respectively. This is probably, though not certainly, an Eocene horizon.

At Castle Hayne a hard, ferruginous, and unsatisfactory water was obtained from a Peedee horizon at a depth of 70 feet.

Detailed information concerning a number of the above-mentioned wells is given below in the table of well data.

Assays and analyses of waters from this county are given elsewhere in this report, as follows: Table 1, pp. 498-501, assays Nos. 119-137; Table 2, pp. 506, 507, analyses Nos. 40, 41. These are discussed on page 489.

Artesian Prospects.—The principal horizons of potable artesian waters within the limits of New Hanover County occur in beds of the Peedee formation, and in a belt several miles wide bordering the coast in overlying Eocene beds. The lower limit of potable waters is indicated approximately in the sections (pp. 438, 439) by dotted lines. At greater depths than that indicated highly saline waters may be expected in all parts of the county. At lesser depths, usually not exceeding 200 feet, potable and in many places excellent waters may be obtained. There are certain exceptions, however, for at a few places the waters obtained have been unsatisfactory owing to their high content of calcium or iron, or both, as in the well of W. H. Shearrin at Castle Hayne. The conditions which give rise to these exceptions are of local extent, and their place of occurrence can only be determined by drilling. But where an unsatisfactory water is obtained from one horizon, a better water may sometimes be secured by casing this off and sinking the well to other deeper horizons. In the belt along the coast where the Eocene beds become important as water-bearers there seems to be little difference between the water obtained from them and that obtained from underlying Peedee horizons, and therefore from an economic standpoint there is no need of discussing them separately.

COUNTY.

Yield per minute. Flow—gallons.	Yield per minute. Pump—gallons.	How obtained at surface.	Use.	Geologic horizon and character of water-beds.	Remarks.
strong flow.	....	flows.	....	Peedee and Black Creek formations.	Nonflowing horizons at 30 and 90 ft., and flowing horizons at 379, 496, 518, 574, 989, 992, 1011 and 1019 ft. Lengths and sizes of casing: 600′—12″; 720′—10″; 1020′—8″; 1109′—6″. Granite struck at 1109. See sec., p. 163. See analysis No. 40, table 2, pp. 506, 507.
....	....	hand force pump.	domestic.	Peedee formation; sand layers in rock.	

NEW HANOVER

Number.	Location.	Owner.	Date completed.	Elevation of surface above datum.	Datum.	Depth—feet.	Diameter—inches.	Depth to principal water supply—feet.	Height of water, + surface feet.
3	Wilmington, 202 S. Front St., at Wilm. Steam Ldy.	J. T. Harper	1906	15	sea level.	58	3½	......	—15
4	Wilmington	W. E. Worth & Co. Ice Factory.	1884	24±	sea level.	101	12	97	—20?
5	...do	...do	......	8	sea level.	55	12	50?	— 4
6	...do	...do	......	18	sea level.	79	12	60	—14
7	Wilmington, at oil mill	W. E. Worth	......	30	sea level.	92	12	74	—23
8	Wilmington, near cor. Dock and Water sts.	...do	......	6	sea level.	62	4	60	— 5
9	Wilmington	Wilmington Iron Works	1895	7	sea level.	50?	4	......	—12
10	Wilmington, bet. Wooster and Queen sts., S. of Surry St.	Van Boklen Property	......	6	sea level.	56	......	......	......
11	Wilmington	Independent Ice Factory	1902	40?	sea level.	175	5	70	—35?
12	...do	...do	1904	40?	sea level.	100	......	70	—35?
13	Wilmington, near cor. Fifteenth and Market sts.	E. L. Halloway	1905	30?	sea level.	42	2	36	—14
14	Wilmington, Market St. bet. Tenth and Eleventh sts.	W. A. Wilson, Jr.	1904	30?	sea level.	45?	3½	......	......
15	Wilmington, City Hall	City	1904	25?	sea level.	70	3½	65	—25?
16	Wilmington, Church St., bet. Front and Surry sts.	J. T. Harper	......	40?	sea level.	98	3	94	—40?
17	Wilmington, ½ mile N. of Hilton Park.	Angola Lumber Co	......	6	sea level.	60	3½	57	.....
18	Wilmington, 2-3 miles E. of	Carolina Trucking Development Co.	1905	30?	sea level.	78	3	46	— 4
19	Wilmington, 1 mile E. of, near trolley line.	Delgado Cotton Mills	1900	40?	sea level.	90	1¼	89	— 8
20	Castle Hayne	W. H. Shearrin	1904	about 23.	sea level.	70	3½	65	—12
21	...do	Carolina Trucking Development Co.	1906	25?	sea level.	370	3?	......	+ 2
22	Winter Park Garden, 3 miles E. of Wilmington.	Henry McMillan, Wilmington, N. C.	1906	40?	sea level.	140	4½	90	— 3
23	...do	Winter Park Garden Co., Wilmington, N. C.	1906	40?	sea level.	161	......	......	.....
24	Masonboro Sound, 7 or 8 miles S. E. of Wilmington.	W. L. Parsley	1906	6	sea level.	187	3	below 130.	— 26
25	Greenville Sound, 6 miles E. of Wilmington, near tracks of C. L. and P. R. R.	Thomas F. Bagley	1906	6	sea level.	170	2½	below 120.	+10
26	Greenville Sound	C. W. Worth	1904	8	sea level.	182	3½	152	+ 8
27	The Hummocks, Wrightsville Sound.	Consolidated Railways Light and Power Co.	1905	5	sea level.	198	3	172	± 0
28	Wrightsville Beach	Tarrymore Hotel	1905	8	sea level.	195	3	175	— 4
29	Wrightsville Beach, at Lumina Park.	Consolidated Railways Light and Power Co.	1905	5	sea level.	198	3	172	± 0
30	Wrightsville, ½ mile W. of P. O.	Mrs. G. M. Croft	1902	15	sea level.	390	2	85	—15

COUNTY—CONTINUED.

Yield per minute. Flow—gallons.	Yield per minute. Pump—gallons.	How obtained at surface.	Use.	Geologic horizon and character of water-beds.	Remarks.
....	....	steam pump.	steam laundry.	Peedee formation; sand.	Another similar well in use at laundry.
....	200	steam pump.	manufacture of ice.	Peedee formation; sand strata alternating with rock strata.	See water assay No. 130, table 1, pp. 500, 501.
....	200	steam pump.	manufacture of ice.	Peedee formation; sand strata alternating with rock strata.	
....	135	steam pump.	manufacture of ice.	Peedee formation; sand strata alternating with rock strata.	See water assay No. 129, table 1, pp. 500, 501.
....	135	steam pump.	boiler, etc.	Peedee formation; sand strata alternating with rock strata.	
....	good supply.	....	....	Peedee formation; sand strata alternating with rock strata.	
....	....	steam pump.	boiler and domestic.	Peedee formation; sand strata alternating with rock strata.	
....	....	....	....	....	
....	100	steam pump.	manufacture of ice.	Peedee formation; sand strata alternating with rock strata.	
....	200	steam pump.	manufacture of ice.	Peedee formation; sand strata alternating with rock strata.	
....	....	pitcher pump.	domestic.	Peedee formation; sand strata alternating with rock strata.	
....	....	hand force pump.	domestic.	Peedee formation; sand strata alternating with rock strata.	
....	....	hand force pump.	public pump.	Peedee formation; sand strata alternating with rock strata.	See water assay No. 125, table 1, pp. 498, 499.
....	....	hand force pump.	domestic.	Peedee formation; sand strata alternating with rock strata.	
....	....	hand pump.	drinking.	Peedee formation; sand strata alternating with rock strata.	See water assay No. 133, table 1, pp. 500, 501.
....	small.	hand pump.	drinking.	Peedee formation; sand strata alternating with rock strata.	
....	....	hand pump.	domestic and drinking.	Peedee formation; sand strata alternating with rock strata.	Ten or twelve similar wells at mill and village. See water assay No. 134, table 1, pp. 500, 501.
....	small.	hand pump.	domestic.	Peedee formation; sand and rock.	
....	....	....	abandoned.	Peedee formation; sand.	Nonflowing horizons, 15-40 and 270-338 ft. Flowing horizon, 338-370 ft. See sec., p. 162.
....	....	pitcher pump.	domestic.	Peedee formation? sand layers in rock.	Water may come from base of Eocene. See sec., p. 167.
....	....	hand pump.	domestic.	Peedee formation? sand.	Water may come from base of Eocene.
12	....	flows.	domestic.	Peedee formation? sand.	Another horizon 60-90 ft. See sec., p. 168.
12	....	flows.	domestic.	Eocene; alternating sand and rock layers.	See sec., p. 193.
10-12	....	flows, hyd. ram.	domestic.	Eocene? or Peedee? formation; sand, rock.	See water assay No. 121, table 1, pp. 498, 499.
....	25	steam pump.	drinking, etc.	Eocene? or Peedee? formation; sand, rock.	
....	25	power pump.	hotel purposes.	Eocene; sand and rock.	
....	25	power pump.	drinking, etc.	Eocene; sand and rock.	
....	abundant supply.	pump.	domestic.	Eocene.	Another horizon at 30 ft. Peedee beds probably penetrated in lower part of well.

NORTHAMPTON COUNTY.

Topography.—There are no topographic maps covering any portion of the area of this county. A few field observations have been made, however, and some data have been obtained from railroad elevations. The Chowan terrace plain of the Pleistocene borders Roanoke River at probable elevations of 50 to 60 feet. This plain is probably present, also, along Meherrin River. The next higher Pleistocene plain, the Wicomico, is believed to cover a considerable area in the east and southeast at elevations of 70 to 100 feet. The Sunderland plain covers a portion of the northern and central part of the county at probable elevations of 110 to 150 feet. A considerable portion of the narrow area which extends westward north of Roanoke River consists of rolling hills with elevations probably amounting to 300 or 400 feet above sea level.

Geology.—Basement rocks form the hills in the western part of the county. They are mantled over in part by discontinuous patches of sandy clays, sands, and gravels of the Lafayette formation. The uneven rock surface dips to the eastward and passes beneath the deposits of the Coastal Plain. In the eastern part of the county beds of the Patuxent formation, consisting principally of compact, arkosic sands and drab clays, rest upon the rock surface. These do not rise more than a few feet above water level in Roanoke River. Miocene beds consisting of sands, clays, and shell marls rest upon the Patuxent surface and overlap westward upon the basement rocks, and, except for a portion of the long, narrow strip extending westward, underlie the whole county beneath the thin, surficial, Pleistocene terrace deposits. The latter, consisting of sandy loams, sands, and gravels, belong to the Coharie, Sunderland, Wicomico, and Chowan formations.

Water Resources.—The lower sandy portions of the Pleistocene formations and the upper sandy beds of the Miocene are the principal sources of water for domestic purposes. The wells range in depth from 10 to 50 feet, the average for driven wells being about 30 feet and for dug wells about 15 feet. A few wells have been driven as deep as 60 to 80 feet, which have obtained a sulphurous, ferruginous water from the Miocene beds. In the extreme western part of the county, in the vicinity of Ingram and Vulture, the open wells range in depth from 10 to 80 feet. The water comes from basement rocks. A few springs are also used in this section.

But one flowing well exists in the county. This is located at Margarettsville on a low terrace bordering a tributary of the Meherrin River. The flow is small. The reported depth of the well is 163 feet.

Several water-bearing beds were encountered. Several other deep wells have been drilled in different parts of the county, all of which failed to obtain a sufficient supply of water. At Jackson the basement rocks were encountered 260 feet below the surface. At 140 feet a gravel bed yielded a small amount of water which rose to within a few feet of the surface. Shells were reported in this well at depths of from 39 to 79 feet.

About 10 years ago two attempts to obtain artesian water were made at Rich Square. A depth of 160 feet was attained in the deepest, but no water was found below 40 feet in either well.

In a well at Garysburg, at the plant of the Garysburg Manufacturing Company, a supply of water is obtained at a depth of 67 feet. The casing was originally driven to a depth of 140 feet, but failing to obtain a supply, it was withdrawn sufficiently to admit the water from the 67-foot horizon.

Recently two deep wells have been drilled at Seaboard, but only small amounts of water were obtained.

Detailed information concerning several of the deep wells are given in the table below.

Assays of waters from this county are given in Table 1, pp. 500, 501, assays Nos. 138, 139. These are discussed on page 489.

Artesian Prospects.—The sandy beds of the Miocene will in most places furnish a good supply of potable water. Owing to the presence of shells, it will at some places be high in calcium carbonate and therefore hard; in some localities it may also be ferruginous. The more sandy, porous beds of the Patuxent formation which underlies the Miocene at depths about on a level with the water in Roanoke River in the central part of the county, and becoming deeper to the eastward, may be expected to furnish good supplies. Overflows are not to be expected except in the lower lands bordering the large streams. It appears that several of the deeper wells have been abandoned, not because of failure to obtain water, but because of failure to obtain flows at the surface.

NORTHAMPTON

Number.	Location.	Owner.	Date completed.	Elevation of surface above datum—feet.	Datum.	Depth—feet.	Diameter—inches.	Depth to principal water supply—feet.	Height of water, + surface feet.
1	Jackson	County	1888			286	2½		
2	Seaboard	Town	1907			162	2	162	−130
3	Margarettsville	Town	1898	55	sea level.	163	2		+ 1

ONSLOW COUNTY.

Topography.—On account of the lack of topographic maps, the detailed relief of the county is not known. Such data as are obtainable from railroad profiles and field observations seem to indicate the presence, over much of the eastern part of the county, of the Chowan terrace plain of the Pleistocene at elevations of 30 to 40 feet, and over at least portions of the western part of the county, of the Wicomico plain at elevations of 50 to 70 feet. The lowest or Pamlico plain is probably present to a very limited extent along the coast and bordering New River.

Geology.—The geology of this county is not known in much detail. Beneath thin, surficial, Pleistocene deposits lies a light-colored, porous, sandy, shell limestone of Eocene age which outcrops in the valley of New River and probably underlies the whole county. This has been referred to the Trent formation. Sinks holding small lakes have been formed in the valley of New River by the caving in of caverns in this limestone. At some depth, perhaps not exceeding 200 feet in the western part of the county, the Eocene limestone is underlain by the Peedee formation. In places thin sheets of Miocene shell marl intervene between the Eocene surface and the overlying Pleistocene deposits. The latter, which consist of sandy loams, sands, and clays, belong to the Wicomico, Chowan, and Pamlico formations.

Water Resources.—Shallow open and driven wells are in use throughout the county. These range in depth from 7 to 25 feet. The water

COUNTY.

Yield per minute.		How obtained at surface.	Use.	Geologic horizon and character of water-beds.	Remarks.
Flow—gallons.	Pump—gallons.				
....	....	....	not used.	gravel and sand.	Basement rocks struck at 260 ft. Water horizons at 20-39, 80 and 142 ft.
....	....	force pump.	drinking.	Patuxent formation? sand and gravel.	Another horizon at 62 ft.
$\frac{1}{4}$	....	flows.	domestic.	Patuxent formation.	

from the surficial Pleistocene beds is usually soft, but at many places the wells enter the underlying shell or limestone beds, in which case the water is hard and unsatisfactory for most purposes.

A number of deep wells have been drilled in the county. Information concerning a few of these is included in the table given below. With the exception of a deep well at Richlands (225 feet) and one at Catharine Lake (210 feet), which may possibly enter underlying Peedee beds, all obtain their supply from the porous, Eocene limestone. Abundant supplies are obtainable, but the water is in most instances hard.

Assays and one analysis of waters from this county are given elsewhere in this report, as follows: Table 1, pp. 500, 501, assays Nos. 140-145; Table 2, pp. 506, 507, analysis No. 42. These are discussed on page 489.

Artesian Prospects.—The porous, Eocene limestone rock, which underlies much or possibly all of this county, is the principal water-bearing terrane. Large supplies may be expected. In the north, Peedee beds will be penetrated at perhaps 200 feet below the surface and may yield a potable water. Farther east in the vicinity of Jacksonville these beds lie deeper, probably 300 feet or more below the surface, and it can hardly be hoped that they will yield a better water than that from the Eocene beds. At depths exceeding 400 or 500 feet water from the Peedee beds is apt to be too salty for ordinary purposes.

[illegible]

Number	Location	Owner	Date completed	Elevation of surface above datum	Datum	Depth, feet	Diameter, inches	Depth to principal water supply, feet	Height of water above surface, feet
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
2	do.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
3	do.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
4	do.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
5	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]		
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
7	[illegible]	[illegible]				[illegible]	[illegible]		
8	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		
9	do.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
10	do.	[illegible]		[illegible]	[illegible]	[illegible]			[illegible]
11	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]		[illegible]
12	[illegible]	[illegible]				[illegible]	[illegible]		
13	do.	do.				[illegible]	[illegible]		[illegible]

PAMLICO COUNTY.

Topography.—With the exception of a strip a few miles wide along the western border the surface of this county is low and level, probably not exceeding [illegible] feet above the sea, and much of it is swampy. It forms a part of the lowest or Pamlico terrace plain of the Pleistocene, which has a widespread development in the counties bordering the sounds of eastern North Carolina. The belt along the western border forming the exception noted above is made up of low, rolling sandhills, and probably forms the eastern edge of the next higher or Chowan terrace plain. These sandhills are separated from the Pamlico plain by a well-defined scarp running north and south which may be seen just to the east of Arapahoe and Grantsboro.

Geology.—The surface materials over the whole county consist of Pleistocene sands, sandy loams, and clays belonging to the Chowan and Pamlico formations. It is probable that in the eastern part of the county these deposits, which are of terrace origin, are underlain by marine Pleistocene deposits consisting of sands and shell marls. Beneath the Pleistocene beds the entire county is underlain by deposits of Tertiary age. Those immediately beneath the Pleistocene are probably referable to the Pliocene, although these may not outcrop at the surface. They consist of sands, clays, and shell marls. Similar beds of Miocene age underlie the Pliocene. These may rise above tide level

COUNTY.

Yield per minute. Flow—gallons.	Yield per minute. Pump—gallons.	How obtained at surface.	Use.	Geologic horizon and character of water-beds.	Remarks.
				Trent formation; limestone and sand.	Abandoned.
1-5				Trent formation; limestone and sand.	See water assay No. 141, table 1, pp. 500, 501.
	3½			Trent formation; limestone and sand.	
				Trent formation; limestone and sand.	
				Trent formation; limestone and sand.	
				Trent formation; limestone and sand.	
				Peedee formation?	
				Peedee formation?	
	15			Trent formation; limestone and sand.	
				Trent formation; limestone and sand.	
				Trent formation; limestone and sand.	
				Trent formation; limestone and sand.	Abandoned.
	5			Trent formation; limestone and sand.	See water assay No. 145, table 1, pp. 500, 501.

in the western part of the county, but this has not been ascertained with certainty. It is probable that Eocene beds occur beneath the Miocene, nowhere, however, rising above tide level; and beneath the Eocene, in turn, at still greater depths are beds of Cretaceous age. The strata of both the Cretaceous and Tertiary dip slightly to the eastward and become deeper beneath the surface in that direction. Owing to the complete covering of surficial terrace deposits, there are few if any natural outcrops of beds of pre-Pleistocene age.

Water Resources.—In the higher sandy area along the western border, soft water is obtained at Arapahoe, Grantsboro, and Prescott by means of open and driven wells 5 to 20 feet in depth. (See assay No. 146, Table 1, pp. 500, 501.) Three 10-foot driven wells, 1¼ inches in diameter, at Prescott, drawing from these sand deposits furnished sufficient water for an 80 horse-power boiler at a shingle mill.

On the low plain which covers the remainder of the county the shallow open and driven wells yield very unsatisfactory water, and cisterns are depended upon almost entirely as a source of supply. If these wells are sunk deep enough to obtain a permanent supply, they penetrate in most instances the deposits of shell marl which lie within a few feet of the surface, the water from which is hard. Where they do not reach the marl the water is soft, but as a rule highly colored by organic matter. The open wells are from 8 to 10 feet in depth, while the driven wells are somewhat deeper.

A number of deep wells have been sunk within the county limits. (See table of well data below for partial list.) The water obtained as a rule has a sulphurous taste and odor. Flowing wells are obtained in the eastern part of the county at locations where the mouth of the well is less than 5 feet above sea level. In the case of wells 150 feet or more in depth it is probable that a somewhat higher pressure would be developed, bringing the water up to 8 or 10 feet above sea level.

At Bayboro the Banner Lumber Company recently drilled a 4-inch well to a depth of 150 feet. No overflow was obtained, but the well yielded plenty of water on pumping. This mill has two or three smaller wells 60 to 70 feet in depth. A 52-foot well near the courthouse yields a plentiful supply of hard water with a disagreeable taste. (See Assay 147, Table 2.) A 47-foot well situated on low land near the town is reported to overflow 12 inches above the surface. At Stonewall slight overflows are obtained in the lowlands at depths of 40 to 50 feet. Two wells, each 157 feet deep, at Arapahoe yielded sulphurous water, but no overflows. In Reelsboro two wells have been sunk, 136 and 160 feet in depth, respectively. These furnished sulphurous water, rising nearly to the surface. Several years ago the John L. Roper Lumber Company drilled a 160-foot well at Oriental and obtained a flow. The well was abandoned because of the hard and sulphurous nature of the water,

PAMLICO

Number.	Location.	Owner.	Date completed.	Elevation of surface above datum—feet.	Datum.	Depth—feet.	Diameter—inches.	Depth to principal water supply—feet.	Height of water, ± surface—feet.
1	Hobucken, 1 mile S. of	W. Ireland	about 1890.	3½	sea level.	210	3	....	+2
2	Hobucken, 1½ miles N. of	Roanoke Railroad and Lumber Co.	1906	4	sea level.	200	2	....	+2
3	Mesic	School	about 1904.	......	a little above sea level.	125	2½	....	+1
4	Vandemere	R. Miller	1906	......	a little above sea level.	82	1½	82	0
5	....do	Pamlico Lumber Co.	about 1901.	0	sea level.	58	2	....	+4
6	....do	W. C. Holton	1906	......	a little above sea level.	62	1½	57	—2
7	....do	Caroline Robbins	1906	......	a little above sea level.	54	1½	54	......
8	Reelsboro, ¾ mile W. of	Seth Hughes	1897	......	....	136	1½	....	......
9	Ashwood	Levi Wharton	1905	......	....	65	1½	....	—3

PASQUOTANK COUNTY.

Topography.—The surface of this county is low and nearly level, and lies entirely within the lowest or Pamlico plain of the Pleistocene. A portion of the Dismal Swamp is included within the county limits. In the extreme northwest the surface slightly exceeds 20 feet above sea

which rendered it unfit for boiler or domestic use. Very small flows are reported at Oriental from wells 25 to 30 feet in depth. The water is slightly hard and ferruginous. Several wells 50 to 80 feet in depth have been driven at Vandemere. The well of the Pamlico Lumber Company, located in the creek channel where the water is about 10 feet deep, yielded a strong flow at a depth of 50 or 60 feet, the top of the pipe being 2 feet above the river level. The flow is reported to vary with the level of the water in the river and to increase with a northeast wind. Another well at an oyster cannery, driven to a depth of 100 feet, furnished a very hard sulphurous water, and was therefore abandoned. Two of the strongest flowing wells in the county have been obtained in the extreme northeast near Hobucken. The water is strongly sulphurous.

Assays of waters from this county are given in Table 1, pp. 500, 501, assays Nos. 146-152. These are discussed on page 490.

Artesian Prospects.—In all parts of the county water can be obtained at depths of from 50 to 200 feet or more. Except in the higher area in the west, the water will rise nearly to the surface, and where the surface is less than 5 or 6 feet above sea level will overflow. The flows in most cases will be small. At depths exceeding 350 or 400 feet salty water is apt to be encountered.

COUNTY.

Yield per minute.		How obtained at surface.	Use.	Geologic horizon and character of water-beds.	Remarks.
Flow—gallons.	Pump—gallons.				
....	....	flows.	....	Miocene.	Other horizons at 60 and 120 ft.
6	30	flows and pumped by steam.	domestic and boiler.	Miocene; shell-rock.	
....	....	....	....	Miocene.	
....	....	hand pump.	domestic.	Miocene? or Pliocene?	Other horizons at 37 and 62 ft.
....	....	flows.	drinking and boiler.	Miocene? or Pliocene? sand.	
....	....	pump.	domestic.	Miocene? or Pliocene? white sand.	
....	....	....	domestic and stock.	Miocene? or Pliocene? white sand.	
....	....	pump.	domestic.	Eocene; rock.	
....	....	pump.	boiler and domestic.	Miocene? or Pliocene? sand.	

level. Towards the southeast it gradually becomes lower, until along Albemarle Sound it is only about 5 feet above the sea.

Geology.—Fine sands and sandy loams of the Pamlico formation form the surface materials over the entire county. These conceal beds of sand, clay, and shell marl, probably for the most part of Pleisto-

cene age, but possibly in part of Pliocene age. At greater depths occur similar beds of Miocene age. At undetermined depths, but probably at something like 700 to 800 feet below the surface, the Tertiary beds are underlain by strata of Cretaceous age.

Water Resources.—The lower sandy beds of the Pamlico deposits supply most of the water for domestic use in the county. Both open and driven wells are used and range in depth from 8 to 30 feet. The amount of water obtained from the driven wells is very large. At the plant of the Crystal Ice and Coal Company on the shore of Pasquotank River in Elizabeth City five 2-inch driven wells yield 1,000 gallons a minute. This water is used, however, only when the Pasquotank River becomes salty. Cisterns are used by some of the inhabitants of [illegible] and [illegible].

Numerous springs occur along the swamps bordering the rivers in the county where the basal water-bearing sands of the terrace deposits have been cut into by erosion. These springs are but little used.

Elizabeth City, situated at the head of the estuarine portion of the Pasquotank River, is supplied by a system of waterworks owned by the Elizabeth City Water and Power Company. The water is obtained from Knobbs Creek 1 mile above its junction with the Pasquotank River. The creek is a sluggish stream, having the characteristic brownish color common to the streams of this region. The water is filtered after treatment with sulphate of alumina and soda. Most of the color is removed by the treatment, and the supply seems fairly good, although the inhabitants are not all satisfied with it. About 300 houses are supplied by the city water. In a boring [illegible] feet deep made by the water company sulphurous water was encountered from a depth of [illegible] feet to the bottom. At the Crystal Ice and Coal Company's plant a well was sunk to a depth of [illegible] feet, but on account of failure to obtain water the casing was withdrawn to 33 feet. About [illegible] years ago the company sunk a 3-inch well to a depth of about [illegible] feet and obtained a plentiful supply of hard, sulphurous water which rose nearly to the surface. The hardness of the water prevented its use and the well was abandoned.

In 1906 Mr. Henry E. Kramer, Jr., bored ten wells in different parts of the town, having an average depth of about 44 feet. Several of these, which were located on low ground, overflowed. Two water-bearing strata were penetrated at depths of about [illegible] and 78 feet, respectively, below the surface. The water from both strata is strongly sulphurous. See records in Table [illegible].

[illegible]

At the Ward Brick Yard a well was drilled to a depth of 326 feet, but after passing through the surface soil, nothing but blue clay was encountered to the bottom and no water was found.

In the western part of the county, near Parkville (P. O. Canaan), a 2-inch well was drilled in 1903 to a depth of 615 feet on the farm of Mr. T. G. Skinner. Water was found at depths of 14, 36, 60, and 260 feet. Below about 300 feet, however, only very salty water was encountered, which rose nearly to the surface.

Artesian Prospects.—Owing to the high content of lime in the Tertiary beds which make up the materials for several hundred feet beneath the surface, water from these horizons will in most cases be hard. It will also be sulphurous and ferruginous in many cases. At depths exceeding 300 or 350 feet the water will be too salty for ordinary uses. Overflows are possible only on lowlands less than 10 feet above sea level.

PENDER COUNTY.

Topography.—Owing to the lack of topographic maps, the surface features of the county are but imperfectly known. Railroad elevations, however, seem to indicate the presence, over the greater part of the county, of the Wicomico terrace plain of the Pleistocene at elevations of 50 to perhaps 70 feet above sea level. Cape Fear, Northeast Cape Fear, and Black rivers are bordered by the next lower or Chowan plain at elevations of 30 to 40 feet, and this plain may cover limited areas in the southeastern part of the county. The lowest or Pamlico plain is probably developed to a limited extent along the rivers mentioned, at elevations not exceeding 20 or 25 feet. A portion of Great Angola Bay or Pocoson (swamp) lies to the north of Holly Shelter Creek, while to the south of this creek a vast stretch of country is covered by Holly Shelter Swamp.

Geology.—The entire county is underlain by beds of Cretaceous age, consisting of marine sands, clays, and marls. In the extreme western part of the county these belong to the Black Creek formation. The beds dip to the southeastward and pass beneath the Peedee formation, also of Cretaceous age. Depressions or basins in the upper undulating Cretaceous surface, which are more or less disconnected, are filled with Eocene limestones. Over this Cretaceous-Eocene surface occur thin sheets of Miocene sands and clays, which, however, are not continuous, but whose extent is imperfectly known. All older formations are covered over and concealed, except very locally, by Pleistocene sands, loams, and clays of the Wicomico, Chowan, and Pamlico formations.

Assays of waters from this county are given in Table 1, pp. 500, 501, assays Nos. 153-155. These are discussed on page 490.

Water Resources.—The Pleistocene deposits covering the surface of the county yield from their basal sandy layers moderate supplies of soft water. It is obtained by means of open dug wells or driven wells which seldom exceed 15 or 20 feet in depth. This source probably furnishes the larger part of the water used for domestic purposes.

Some deep wells have been drilled in the county, and information has been received regarding a number of them. The reader is referred to the table of well data given below for detailed information.

Artesian Prospects.—The Cretaceous deposits belonging in part to the Black Creek formation which outcrops in the western part of the county and dip gently to the eastward, and in part to the Peedee formation which overlies the Black Creek in the eastern half of the county,

PENDER

Number.	Location.	Owner.	Date completed.	Elevation of surface above datum—feet.	Datum.	Depth—feet.	Diameter—inches.	Depth to principal water supply—feet.	Height of water, ± surface—feet.
1	Willard	J. M. Johnson		about 51.	sea level.	135	1½		—20
2	Willard, 1 mile S. of	Angola Lumber Co.	1903	about 65.	sea level.	165	3½	160	—17
3	Willard, 1 mile from	E. M. Johnson	1900	15	level of creek.	145	1½		— 5
4	Atkinson, 4 miles W. of, at store.	Ed. Sellers	about 1895.	6	level of Black River.	75	1½	75	+ 0
5	Olga, 2½ miles E. of	W. M. Corbett				25±	1½	20	0
6	Watha	Fitzhugh Lumber Co.	1903	60	sea level.	175	4½	170	—17
7	Burgaw	Burgaw Manufacturing Co.	1903	57	sea level.	80	5	65	—12
8	St. Helena, 2½ miles S. of Burgaw.	Carolina Trucking Development Co., Wilmington	1906	45±	sea level.	220	4½	220	—13
9	Rocky Point	J. L. Casteen	1897	40	sea level.	45	1½	45	— 8
10	do	J. C. Jones	1900	44	sea level.	54	2	50	?

PERQUIMANS COUNTY.

Topography.—With the exception of a narrow strip in the northwest, a broad and but very slightly dissected plain with elevations scarcely exceeding 20 feet above sea level spreads over the entire county. This forms a part of the Pamlico plain, which is the lowest of the Pleistocene terraces. Along a distance of about 9 miles in the northwestern part of the county the next higher or Chowan plain is present as a narrow strip about a mile wide with elevations slightly exceeding 50 feet.

Geology.—The surface materials over the entire county are of Pleistocene age. They consist of fine sands, sandy loams, and clays belonging to the Chowan and Pamlico formations. These are underlain at shallow depths by sands, clays, and shell marls which are probably in

contain lenses and layers of rather loose sand which should furnish supplies of potable water. In some instances the water derived from these sources will be hard, owing to the solution of lime from shells, in some of the beds. Practically all over the county salty water is apt to be encountered at depths exceeding 300 or 400 feet below the surface.

At Rocky Point and in the immediately surrounding region porous Eocene limestone is encountered at a depth of about 50 feet, which yields a hard water. Eocene limestone is believed to underlie a strip of country about 10 miles or more in width bordering the coast on the southeast, and although few wells have been drilled here and no information is at hand concerning them, it is probable that potable water may be obtained from them.

COUNTY.

Yield per minute.		How obtained at surface.	Use.	Geologic horizon and character of water-beds.	Remarks.
Flow—gallons.	Pump—gallons.				
....	....	hand pump.	domestic.	Black Creek formation; sand.	See water assay No. 155, table 1, pp. 500, 501.
....	10	steam pump.	drinking and boiler.	Black Creek formation; shell-rock, hard and soft.	
....	....	pitcher pump.	domestic.	Black Creek formation; sand.	
$\frac{3}{4}$	....	flows.	domestic.	Black Creek formation.	See water assay No. 153, table 1, pp. 500, 501.
....	....	....	domestic.	Black Creek formation; sand.	
....	25	steam pump.	boiler.	Peedee formation; shell-rock?	
....	25	steam pump.	boiler.	Peedee formation; fine sand.	
....	good supply.	force pump.	domestic.	Peedee formation; sand.	Another horizon at 40 ft.
....	10	hand pump.	domestic.	Eocene; sand.	Several other horizons.
....	....	hand pump.	domestic.	Eocene; limestone.	Another horizon at 46 ft.

part of Miocene and possibly in part of Pliocene and of Pleistocene age. The former are believed to immediately underlie the terrace covering in the west. They dip gently eastward and probably pass beneath Pliocene and Pleistocene beds which are thought to immediately underlie the eastern part of the county. Pre-Pleistocene beds are not known to outcrop at the surface. At considerable depths, perhaps 600 to 800 feet beneath the surface, Cretaceous beds would probably be encountered.

Water Resources.—Over most of this county the water is obtained by means of open and driven wells 8 to 30 feet in depth from the lower sandy portions of the Pleistocene deposits or from sandy beds in the upper part of the Miocene or Pliocene beds. Cisterns are used to some extent in Belvidere and Burgess. At Belvidere one family obtains its

drinking-water from a small spring which, however, fails in dry weather. At Hertford the mills obtain their boiler-feed water from the Perquimans River.

Very few deep wells have been drilled in this county. At Hertford and Winfall the driven wells range from [illegible] to [illegible] feet. At the residence of [illegible] in Hertford a well was drilled to between [illegible] and [illegible] feet in depth, but as no overflow was obtained the casing was pulled and the well abandoned. The water from the deeper source rises to within [illegible] feet of the surface.

Artesian Prospects.—At depths not exceeding [illegible] to [illegible] feet an abundance of potable water may be obtained from the sandy beds of the [illegible]. At greater depths than those indicated [illegible] waters are apt to be encountered. No flowing wells have been reported in any part of the county, but it seems probable that wells [illegible] feet or more in depth and located on ground whose elevation above sea level is less than [illegible] feet would flow a small stream at the surface.

PITT COUNTY.

Topography.—Topographic maps have been made by the United States Geological Survey covering the entire area of this county. These show that four of the Pleistocene terrace plains are present within the county limits and make up its surface. The lowest or Pamlico plain is represented by small areas from [illegible] to [illegible] feet in elevation bordering Tar River and extending upstream to about [illegible] miles above Greenville. The Chowan plain is developed in a belt [illegible] miles in width paralleling Tar River on its north side with elevations ranging from [illegible] to [illegible] feet; it is also represented in the southern part of the county by a portion of a similar belt which parallels Neuse River on the north. The Wicomico plain covers a small area in the northern part of the county and the greater part of the county south of Tar River, at elevations ranging from [illegible] to [illegible] feet. The Sunderland plain covers a small area in the extreme western part at elevations of [illegible] to [illegible] feet. In places these terrace plains are separated from each other by well-defined scarps, but at other places they merge into each other, making it difficult to establish the separating line. The plains have been somewhat dissected by stream erosion.

Geology.—The oldest beds outcropping in the county are those of the Patuxent formation, consisting of rather compact sands and clays. These are found along Tar River from Parker Landing northward, rising to a maximum of about 18 feet above water level. They underlie a small area in the northwestern part of the county. In a belt several miles wide just to the southeast of the preceding area beds of the Black Creek formation, consisting in part of laminated, lignitic

sands and clays, and in part of marine sands and clays, rest upon the southeastward dipping Patuxent beds. They rise to a maximum observed height of 25 feet above water level at Blue Banks Landing on Tar River. In a belt to the southeast of the latter the Peedee formation, consisting of marine greensands and clays, is present, resting conformably upon the Black Creek beds. The Peedee beds dip gently to the eastward beneath overlying Miocene beds. Over the eastern half of the county the latter are the only pre-Pleistocene beds which appear above water level. These Miocene beds overlap and spread westward entirely across the county, resting upon the beveled edges of the Cretaceous formations. Thin, surficial, Pleistocene terrace deposits, consisting of gravels, sands, loams, and clays, spread over the surface of the county and, except locally, conceal all older formations. These are referred to the Sunderland, Wicomico, Chowan, and Pamlico formations.

Water Resources.—The principal water supplies for the county as a whole are obtained from open and driven wells ranging in depth from 5 to 30 or 40 feet or in a few instances to 60 feet. These shallow wells derive their supplies as a rule from the basal sandy and gravelly beds of the Pleistocene formations, although some penetrate water-bearing sands in the underlying Miocene.

Greenville has a system of waterworks deriving its supply from the Tar River near the city. The water is filtered, pumped to a standpipe, and delivered by gravity. A domestic pressure of 45 pounds and a fire pressure of 145 pounds is obtainable. The use of this supply by the inhabitants is rapidly increasing.

A number of deep wells have been drilled in the county. The table contains information concerning some of these. Additional information is given in the notes which follow.

Several deep wells have been drilled at Greenville. Two wells at the Greenville Ice Factory, each 157 feet in depth, when pumped together yield 40 gallons per minute. Pumping at this rate has been continued for two months at a time with no diminution in the supply. At Cox's distillery on the banks of the Tar River, about one-fourth mile above the pumping station, are several flowing wells. Three of these, the depths of which range from 100 to 115 feet, are connected by means of pipes and flow at the rate of 75 gallons per minute about 5 feet above the river level. A small flow was also encountered at 40 feet in these wells. The town had several wells drilled several years ago, but they are not now in use. They obtained a good supply of water at a depth of 75 feet.

The Imperial Tobacco Company has two 60-foot wells and five 30-foot wells, all pumped together. The shallower wells are said to be

inexhaustible with a small Worthington steam pump. A 12-hour test was made on the seven wells with a steam pump having a capacity of 25 gallons per minute. The level of the water was not perceptibly lowered. They are now being pumped at the rate of about 20 gallons per minute. The water gives a slight red scale in boilers.

At Grimesland several wells have been sunk to depths of from 40 to 240 feet, the water rising to within 15 feet of the surface.

The A. G. Cox Manufacturing Company at Winterville obtains its water supply from a 33-foot driven well which penetrates Peedee beds. The water is ferruginous, but is reported to scale but little. This well is pumped 10 hours a day at the rate of 5½ gallons per minute.

On the farm of G. W. Cox, 6 miles east of Ayden, on land the elevation of which is between 20 and 30 feet above sea level, a well driven to a depth of 16 feet yielded a flow of about 2 gallons per minute.

In the town of Grifton deep wells 80 to 125 feet deep and from 1¼ to 5 inches in diameter are used. There are about fifteen deep wells in all, of which the town owns eight. The water rises to within a few feet of the surface. The first well was drilled about 1896. The water comes from limestone layers in the Peedee beds.

At Bruce a water highly impregnated with iron and sulphur was found at a depth of 85 feet in the Black Creek formation. The springs

PITT

Number.	Location.	Owner.	Date completed.	Elevation of surface above datum—feet.	Datum.	Depth—feet.	Diameter—inches.	Depth to principal water supply—feet.	Height of water, ± surface—feet.
1	Grimesland	Alston Grimes	1905	about 40.	sea level.	100			
2	do	do	previous to 1861.	about 40.	sea level.	240	1½?		—12
3	Littlefield	Mr. Lang				150			
4	Ayden	I. J. McLawhorn	1905	67	sea level.	65	1½	65	— 5
5	Ayden, 5 miles from	Mr. Tripp				220	1½		
6	Ayden, 5 miles S. of	J. W. Quinlan Bros.		about 60?	sea level.	114	1½	114	
7	Shelmerdine	Mr. Stokes		about 40.	sea level.	150			
8	Winterville	Bryant Tripp		about 70.	sea level.	140			
9	do	R. H. Hunsucker		72	sea level.	63	1½		
10	Greenville	Greenville Ice Factory	1906	45±	sea level.	157	2		—18
11	Greenville, at Hooker's gin.	O. Hooker	about 1901.	50	sea level.	156	4½		—15?
12	Greenville, Cox's distillery.	do	1906	5	sea level.	101	3		+ 5
13	do	do	1906	5	sea level.	106	2		+ 5
14	do	do	1906	5	sea level.	114	2		+ 5
15	do	do	1903	5	sea level.	40	2		+ 1

issuing from the Black Creek formation at the foot of the escarpment bordering Tar River at this place are reported to be both sulphurous and ferruginous.

Assays and one analysis of waters from this county are given elsewhere in this report, as follows: Table 1, pp. 500-503, assays Nos. 156-162; Table 2, pp. 506, 507, analysis No. 43. These are discussed on page 490.

Artesian Prospects.—Over the entire county the Miocene beds offer a source of artesian supply. Water from this source will in most cases be potable, but on account of the presence of shell marl is apt to be hard. Water from the Peedee beds which underlie the Miocene is also apt to be hard for the same reason. The Black Creek beds along the belt where they appear above water level, and for some distance to the eastward of where they pass under the Peedee formation, should furnish abundant supplies of water, in most cases potable, but in places rather high in iron salts. The Patuxent beds in the western part of the county at depths of 80 to 100 feet, or more, and for several miles eastward of where they pass under the Black Creek formation at increasingly greater depths should furnish supplies of soft water of excellent quality. Flowing wells can be expected only in the lowlands bordering the streams.

COUNTY.

Yield per minute. Flow—gallons.	Yield per minute. Pump—gallons.	How obtained at surface.	Use.	Geologic horizon and character of water-beds.	Remarks.
....	....	....	....	Miocene.	Three other wells, 40 to 100 ft. in depth.
....	....	pump.	domestic.	Miocene?	
....	....	....	....	Peedee formation.	
....	....	pump.	domestic.	Peedee formation; gravel?	
....	....	....	....	Peedee formation.	
....	....	....	....	Peedee formation.	
....	....	....	....	Miocene?	
....	....	....	....	Black Creek formation?	
....	....	....	....	Peedee formation.	
....	40	steam pump.	boiler and mfg. of ice.	Black Creek formation?	Another similar well, the two pumped together. See water assay No. 157, table 1, pp. 500, 501.
....	abundant supply.	rotary pump.	boiler.	Black Creek formation?	
25	....	flows.	mfg. of beverages.	Black Creek formation.	Another horizon at 40 ft. See water assay No. 158, table 1, pp. 500, 501.
25	....	flows.	mfg. of beverages.	Black Creek formation.	Another horizon at 40 ft. See water assay No. 158, table 1, pp. 500, 501.
25	....	flows.	mfg. of beverages.	Black Creek formation.	Another horizon at 40 ft. See water assay No. 158, table 1, pp. 500, 501.
....	....	flows.	....	Peedee formation.	

PITT

Number.	Location.	Owner.	Date completed.	Elevation of surface above datum.	Datum.	Depth—feet.	Diameter—inches.	Depth to principal water supply—feet.	Height of water, + surface feet.
16	Greenville, Cox's distillery.	O. Hooker	1903	5	sea level.	40	1½	....	+ 1
17	Greenville	American Tobacco Co.	1902	60	sea level.	74	4	65–70	—22?
18	....do	Imperial Tobacco Co.	1901	60	sea level.	60	4	60	—10
19	Farmville	C. L. Barrett		75	sea level.	65	1½	65	......
20	....do	John Flanagan		about 80.	sea level.	80	....	....	......
21	....do	....do		about 80.	sea level.	90	....	....	......
22	Bruce, 1 mile S. W. of	R. R. Cotten	1902	82	sea level.	86	4	70	—15
23	Grifton	W. G. Garris	1906	30	sea level.	100	1½	100	—10?

RICHMOND COUNTY.

Topography.—Rolling sandhills form the surface over the southeastern or Coastal Plain portion of this county, the elevations ranging from about 225 to over 400 feet above sea level.

Geology.—Basement rocks come to the surface over the northwestern part of the county, being mantled over in part, however, by surficial, sandy clays, sands, and gravels of the Lafayette formation. To the southeast the surface of these rocks passes beneath the arkosic sands and drab, compact clays of the Patuxent formation. The latter probably attains a thickness of 200 to 300 feet along the southeastern border. The very uneven eroded surface of the Patuxent formation is mantled over more or less discontinuously with a surficial covering of sands and gravels of the Lafayette formation.

Water Resources.—In the eastern half of the county open and driven wells 15 to 100 feet in depth yield abundant supplies of water from the Lafayette or underlying Patuxent beds. Water from the well of E. A. Lackey at Hamlet, Assay 163, Table 1, pp. 502, 503, is probably derived from the Patuxent formation. In the central and western parts open wells predominate, the depths ranging from 25 to 100 feet, many of the wells entering the basement rocks. Springs are abundant over the entire county and are much in use.

The deepest well in the county is that owned by W. R. Bonsal at Hamlet. The diameter is 6 inches and the depth 425 feet. Crystalline rock was entered at 200 feet and water was struck at 420 feet, presumably in a crevice. The water rises to within 60 feet of the surface. It is lifted by means of a windmill.

COUNTY—CONTINUED.

Yield per minute. Flow—gallons.	Yield per minute. Pump—gallons.	How obtained at surface.	Use.	Geologic horizon and character of water-beds.	Remarks.
....	....	flows.	....	Peedee formation.	
....	50+	steam pump.	boiler.	Miocene? or Peedee formation.	Three similar wells. Another horizon at 12–18 ft. See water assay No. 160, table 1, pp. 502, 503.
....	25+	steam pump.	boiler.	Miocene? or Peedee formation.	Two similar wells 15 ft. apart.
....	....	force pump.	stock.	Miocene? fine micaceous sand.	See water assay No. 156, table 1, pp. 502, 503.
....	....	....	....	Black Creek formation?	
....	....	....	....	Black Creek formation?	
....	·25	pump.	not used.	Black Creek formation; white sand.	Too highly mineralized for use.
....	....	hand pump.	domestic.	Peedee formation; sand and rock.	Other horizons at 15 and 60 ft. See water assay No. 161, table 1, pp. 502, 503.

At Hamlet Mr. E. A. Lackey owns a small system of waterworks. The water comes from several driven wells 30 feet in depth, and is raised to a 16,000-gallon tank situated on a hill nearby. There are about 40 taps and 8,000 feet of main line. The water is very soft. Other wells at this place have a depth of 60 to 100 feet.

Artesian Prospects.—The rock surface underlying the Coastal Plain materials is very irregular, and it would be impossible to say at what depth it would be encountered in drilling at any given locality. Along the southeastern border, however, it will in most places be 200 to 300 feet below the surface, and here the overlying Patuxent beds should furnish abundant supplies of excellent water. Flowing wells are not to be expected in the county, although the water will usually rise within reach of ordinary pumps. The underlying crystalline rocks are to be regarded as a possible source of artesian supply, but the probability of getting water at any given place depends upon local underground conditions which cannot as a rule be determined by surface observations.

ROBESON COUNTY.

Topography.—No topographic maps have been made of any part of this county. However, elevations obtained from railroad profiles, together with a few field observations, seem to indicate that the surface over the greater part of the county is formed of two Pleistocene terrace plains, namely, the Coharie and Sunderland plains. The former covers about the northwestern half of the county at elevations of about 160 to 220 feet. The latter covers most of the remainder of the county, at elevations of about 120 to 150 feet.

Geology.—The Patuxent formation, consisting of arkosic sands and drab clays, is believed to underlie about the northwestern third of the county. The beds of this formation dip gently to the southeast and pass beneath the overlying Black Creek formation. The latter underlies all the remaining area, with the possible exception of a narrow strip along the southeastern border, where the Peedee formation may be present, resting conformably upon the Black Creek formation. Thin sheets of Miocene sands, clays, and shell marls probably occupying disconnected areas occur resting upon the Black Creek or Peedee beds over about the southern half of the county. Over all older formations is spread a blanket of sandy clays, sands, and gravels, of Pleistocene age, belonging for the most part to the Coharie and Sunderland formations, but in the narrow, lower terraces bordering the larger streams, to the Wicomico formation.

Water Resources.—Over the greater part of the county the inhabitants depend upon the basal sandy and gravelly beds of the Pleistocene formations for their chief supply of water for ordinary purposes. The common method of obtaining water is by means of shallow, open or driven wells ranging in depth from 10 to 30 feet. In a number of communities the people are beginning to recognize the value of the underlying Black Creek and Patuxent beds as sources of artesian water, and numerous wells have been drilled into them, to depths ranging from 40 to 225 feet. The communities where deep wells are most numerous are Red Springs, Fairmont, Raynham, and Lumberton. Partial lists of the wells from these and a few other places are included in the table given below. See Plates XL and XLI.

At Lumberton, the county-seat, a number of wells have been drilled, and on low ground near Lumber River some excellent flows have been obtained. But little detailed information has been secured concerning individual wells. The following general information has been furnished by the mayor, Mr. E. K. Proctor, Jr.:

Several wells were sunk in 1896, the depths ranging from 82 to 114 feet. The first was located on the bank of Lumber River at about low-water level, and about 32 feet below the level of the courthouse square. A flow of about 100 gallons per minute was obtained through a 2-inch pipe. This would rise about 22 feet above low-water level. Since this well was drilled a number of others have been sunk within the town limits, located on ground lower than the general level, which flow from 5 to 35 gallons per minute. One well was drilled by the town to a depth of 400 feet, but the water was found to rise no higher than in the wells mentioned above, and in quality it was not as satisfactory.

A.—Flowing well from strata of the Black Creek formation at Lumberton, Robeson County, N. C. This was the first flowing well obtained in this community.

B.—Flowing well from strata of the Black Creek formation at National Cotton Mills, 1¼ miles west of Lumberton, N. C. This is one of 15 wells supplying water for domestic purposes to the cotton mill employees.

A.—Flowing well from strata of the Black Creek formation at fair grounds, Lumberton, N. C.

B.—Flowing well from strata of the Patuxent formation, near the old hotel building at Red Springs, N C.

At the National Cotton Mills, located $1\frac{1}{4}$ miles west of Lumberton, on a terrace plain bordering Lumber River, believed to be the Wicomico plain, there are 15 flowing wells. These were drilled in 1906. They are located convenient to the dwellings of the cotton mill employees. The depth of each is about 100 feet; the diameter of each is $1\frac{1}{4}$ inches; the average flow is 8 or 9 gallons per minute. The water is slightly ferruginous, but is satisfactory. It is used for domestic purposes only. See Plate XL, B.

At Fairmont and the surrounding region a large number of flowing wells have been obtained at depths ranging from 55 to 225 feet. The water from some of these is ferruginous.

At and near Raynham there are a number of wells ranging in depth from 35 to 110 feet, some of which flow at the surface.

At Red Springs and in the immediate vicinity there are a number of flowing wells with depths ranging from 40 to 100 feet.. The water is high in iron and yields a red precipitate upon exposure to the air. Springs high in iron and yielding a red iron precipitate existed here before the wells were sunk. The town was named from these springs. The water is regarded as having medicinal properties, which has led to the establishment of a health resort. See Plate XLI, B.

A number of other wells have been drilled in various parts of the county from 35 to 100 feet in depth.

Assays and analyses of waters from this county are given elsewhere in this report, as follows: Table 1, pp. 502, 503, assays Nos. 164-167; Table 2, pp. 506, 507, analyses Nos. 44-49. These are discussed on page 490.

Artesian Prospects.—Over about the northwestern one-half of the county water of excellent quality, though in some cases a little high in iron, may be obtained at various depths beneath the surface down to several hundred feet from beds of the Patuxent formation. In many places, usually on ground somewhat lower than the general surface, flowing wells are possible. Over the southeastern half of the county the Black Creek beds furnish the water horizons. Excellent water is to be expected in these beds, also, although in some cases the content of iron salts is apt to be high. Flows are possible in many places, more especially on low ground along the streams.

ROBESON

Number.	Location.	Owner.	Date completed.	Elevation of surface above datum—feet.	Datum.	Depth—feet.	Diameter—inches.	Depth to principal water supply—feet.	Height of water, ± surface—feet.
1	Fairmont	G. Ashley	......	130±	sea level.	155	1¼	155	+ 0
2	...do	W. C. Brown	......	130±	sea level.	170	1¼	....	+12?
3	...do	J. B. Brown	1900	130±	sea level.	150	1¼	150	+ 0
4	...do	J. P. Brown	1905	130±	sea level.	210	1¼	210	+ 0
5	...do	C. B. Thompson	1905	130±	sea level.	180	1¼	180	+ 2
6	...do	F. H. Pittman	1903	130±	sea level.	212	2	200	+ 2
7	...do	C. S. McKinzie	1902	130±	sea level.	57½	1¼	57½	+10
8	Fairmont, 1-6 miles E. of	J. H. Pitman	1905	130±	sea level.	225	1¼	225	+ 8
9	Fairmont, 2 miles N. of	Lewis Pitman	1904	130±	sea level.	180	1¼	180	+ 2
10	Raynham	Raynham Gin Co	1905	160±	sea level.	110	2	110	— 8
11	Raynham, 1 mile W. of	L. R. Hamer	1897?	160±	sea level.	100	2	100	+ 2
12	...do	F. M. Townsend, McDonalds, N. C.	1906	160±	sea level.	110	1½	110	— 6
13	McDonalds	J. L. Townsend	1898	150±	sea level.	100	2	100	+ 2
14	Kingsdale	Southern Sawmills and Lumber Co.	......	120±	sea level.	100	10	100	—18
15	Bellamy, ¾ mile W. of	L. J. Cottingham Lumber Co.	1905	194±	sea level.	151	4	141	— 0
16	Lumberton	A. E. White	1904	120±	sea level.	121	2	100	— 0
17	...do	W. A. Yost	1903	120±	sea level.	100	2	100	— 3
18	Lumberton, 8 miles N. of	D. B. Humphrey, Parkton, N. C.	1905	160±	sea level.	50	2	50	+ 9½
19	Red Springs, 4 miles S. of	Mrs. J. Amanda Brown	about 1897.	170±	sea level.	100±	2?	....	+ 0
20	Red Springs	B. W. Townsend	1890	200±	sea level.	90	2	90	+12
21	...do	S. R. Townsend	1902	200±	sea level.	75	2	75	+ 3
22	...do	J. L. McMillan	1906	180±	sea level.	40	1½	40	+ 3

SAMPSON COUNTY.

Topography.—The north-central part of the county is covered by topographic maps of the U. S. Geological Survey. These, together with railroad elevations, show that the highest and oldest Pleistocene terrace plain, the Coharie, forms the surface over most of the northern three-fourths of the county, at elevations of 160 to 215 feet. The next lower or Sunderland plain is believed to cover considerable areas to the south of Clinton. The Wicomico plain covers much of the southern end of the county, the elevations probably ranging from about 60 to 90 feet; while the Chowan plain, the lowest plain present in the county, borders Black and South rivers for some distance above their

COUNTY.

Yield per minute. Flow—gallons.	Yield per minute. Pump—gallons.	How obtained at surface.	Use.	Geologic horizon and character of water-beds.	Remarks.
....	....	flows.	domestic.	Black Creek formation; sand.	Other horizons at 45 and 70 ft.
....	....	flows.	domestic.	Black Creek formation; sand.	Another horizon at 100 ft.
small.	....	flows.	domestic.	Black Creek formation; sand.	
6	....	flows.	domestic.	Black Creek formation; sand.	Well in house, water pumped into tank by hydraulic ram. Other horizons at 14, 100, and 165 ft.
....	....	flows.	domestic.	Black Creek formation; sand.	Another horizon at 75 to 125 ft.
5	....	flows.	drinking and bottling works.	Black Creek formation; gravel.	Other horizons at 80 and 140 ft.
9	....	flows.	domestic.	Black Creek formation; sand.	Another horizon at 47 ft.
12	....	flows.	domestic.	Black Creek formation; gravel and sand.	Other horizons at 80 and 125 ft.
3	....	flows.	domestic.	Black Creek formation; gravel and sand.	
....	good supply.	steam engine.	boiler.	Black Creek formation; sand.	Other horizons at 20 and 80 ft. Supplies 50 h. p. boiler.
8	....	flows.	domestic and stock.	Black Creek formation; sand and gravel.	Another well 12 ft. higher on hill is 115 ft. deep, and water rises within 8 ft. of top.
....	12	hand pump.	domestic.	Black Creek formation; coarse white sand.	Several horizons; marl bed penetrated at 60 ft.
3	....	flows.	domestic.	Black Creek formation; sand.	
....	150	steam jet.	boiler.	Black Creek formation; sand and gravel.	Other horizons at 24 and 55 ft.
....	....	force pump.	domestic.	Black Creek formation; sand.	
....	....	gasoline engine.	domestic and bottling works.	Black Creek formation; sand.	There are a number of flowing wells at Lumberton. Other horizons at 24 and 55 ft. See text above.
....	6	force pump.	domestic.	Black Creek formation; sand.	
....	....	flows.	domestic.	Black Creek formation; sand.	Has another well similar to this.
6?	....	flows.	domestic.	Patuxent formation.	
20	....	flows.	domestic and medicinal.	Patuxent formation; sand.	
30	....	flows.	domestic and medicinal.	Patuxent formation; gravel.	Has several wells 20-30 ft. deep, and several 75 ft. deep. Another horizon at 25 ft.
5	....	flows.	drinking.	Patuxent formation; sand.	Another horizon at 20 ft.

junction, at elevations of 30 to perhaps 40 or 50 feet. The Chowan plain is separated from the Wicomico plain by a well-defined scarp. The terrace plains are all more or less dissected by streams.

Geology.—The Patuxent formation, consisting of arkosic sands and drab, compact clays, is believed to underlie a strip a few miles wide in the extreme northwest. It passes to the southeast unconformably beneath the Black Creek formation. The beds of the latter formation, consisting of laminated, lignitic sands and clays with interbedded, marine beds in the upper part, underlie the remainder of the county. Pleistocene sandy clays, sands, and gravels form a surficial covering over all older formations. They are referred to the Coharie, Sunderland, Wicomico, and Chowan formations. Kerr has mapped both

Eocene and Miocene beds within the limits of the county, and it is probable that they exist in places as thin sheets intervening between the Cretaceous and the overlying Pleistocene beds. Nothing definite, however, is known concerning them.

Water Resources.—The average depth of the open and driven wells is from 20 to 30 feet. The former range from 10 to 20 feet and the latter in but few cases exceed 30 feet. The water comes from the lower sandy portions of the Pleistocene formations. It is upon these shallow open and driven wells that the majority of the inhabitants of the county depend for their water supplies. A few driven wells in the northwestern part of the county reach depths of 40 or 50 feet, probably penetrating the underlying Patuxent beds. Small springs are frequent along the stream bluffs and escarpments; but little use is made of them.

At a few places where the Black Creek formation lies close to the surface, open wells have penetrated its lignitic portions, which as a rule contain iron sulphide. In such cases the water standing in contact with the iron sulphide soon becomes unfit for drinking purposes. This condition exists at Clear Run, but there the difficulty has been overcome by deeper drilling.

Deep wells have been drilled at a number of places in the county. (See table of well data.) At Clear Run, on a terrace bordering Black River, an abundant supply of soft water (see analysis, Table 2) is ob-

SAMPSON

Number.	Location.	Owner.	Date completed.	Elevation of surface above datum—feet.	Datum.	Depth—feet.	Diameter—inches.	Depth to principal water supply—feet.	Height of water, … surface—feet.
1	Ivanhoe, 1 mile S. of	Mrs. Mary C. McMillan.	1898	40±	sea level.	65	1¼	65	+ 0
2	Alpine	F. R. Corbett	1900	18±	level of Black River.	71	1¼	70?	+ 0
3	do	do	1900	18±	level of Black River.	71	1¼	70?	- 0
4	Alpine, ¾ mile from	do	1897	......	......	88	1¼	......	+ 0
5	Alpine	J. B. Seavey	1906	......	......	100	1¼	80-100	+ 2
6	Alpine, ½ mile W. of	Alpine Turpentine Co., Kerr, N. C.	1905	......	......	75	1¼	75	+12
7	Clear Run	A. J. Johnson	......	18±	level of Black River.	72	1¼	......	+ 0
8	do	do	......	......	level of Black River.	90	1¼	......	+ 0
9	do	do	......	......	level of Black River.	137	1¼	120	− 5
10	do	do	......	......	level of Black River.	80	1¼	......	+ 2
11	Thomas	J. E. Rich	1883	9	level of Great Coharie Creek.	75	1¼	75	+ 2
12	Kennedy's Mills, 5 miles W. of Clinton.	J. J. Kennedy	1905	12	level of Moccasin Swamp.	44	1¼	44	+ 0

tained from sand beds in the Black Creek formation at from 70 to 120 feet below the surface. Three of the deep wells at this place overflow, the strongest at the rate of 8 gallons per minute. At Ivanhoe a flowing well 70 feet deep yields a ferruginous water (see assay, Table 1) from a calcareous layer in the upper part of the Black Creek formation. At Alpine flows are obtained at depths of 80 to 100 feet. There is one flowing well at Delta. At Thomas several wells yield water from the Black Creek formation.

Flows probably from the Patuxent formation occur at Shady Grove and Newton Grove. The elevation of these places is about 150 feet above sea level. The water is reported to contain considerable iron, and in some cases a slight odor of hydrogen sulphide is detected.

Assays and one analysis of waters from this county are given elsewhere in this report, as follows: Table 1, pp. 502, 503, assays Nos. 168-174; Table 2, pp. 506, 507, analysis No. 50. These are discussed on page 490.

Artesian Prospects.—The Patuxent and Black Creek formations should yield an abundant supply of water over the entire county at depths ranging from 40 to 300 feet. Overflows are possible only in the lowlands bordering the streams. On the higher level land away from the streams the same water-bearing horizons will be encountered at correspondingly greater depths, the water in most cases rising within reach of common suction pumps.

COUNTY.

Yield per minute. Flow—gallons.	Yield per minute. Pump—gallons.	How obtained at surface.	Use.	Geologic horizon and character of water-beds.	Remarks.
4-5	....	flows.	domestic.	Black Creek formation; limestone.	See water assay No. 172, table 1, pp. 502, 503.
8½	....	flows.	domestic and turpentine still.	Black Creek formation; sand.	See water assay No. 168, table 1, pp. 502, 503.
2½	....	flows.	domestic and turpentine still.	Black Creek formation; sand.	
8	....	flows.	domestic and turpentine still.	Black Creek formation; sand.	
11	....	flows.	domestic.	Black Creek formation; sand.	
14	....	flows.	domestic and turpentine still.	Black Creek formation; sand.	
2½	....	flows.	domestic and turpentine still.	Black Creek formation; sand.	See water assay No. 169, table 1, pp. 502, 503.
2½	....	flows.	domestic and turpentine still.	Black Creek formation; sand.	
2	....	flows.	domestic and turpentine still.	Black Creek formation; sand.	
2½	....	flows.	domestic and turpentine still.	Black Creek formation; sand.	
6½	....	flows.	domestic and turpentine still.	Black Creek formation; sand.	See water assay No. 174, table 1, pp. 502, 503.
1½	....	flows.	domestic.	Black Creek formation; sand.	See water assay No. 173, table 1, pp. 502, 503.

SAMPSON

Number.	Location.	Owner.	Date completed.	Elevation of surface above datum.	Datum.	Depth—feet.	Diameter—inches.	Depth to principal water supply—feet.	Height of water, ± surface feet.
13	Clinton, 2 miles W. of	Mr. Stuart				115			—25?
14	Clinton	Johnson's Crate Factory		145±	sea level.	180			+ 0
15	Mints, 2½ miles S. W. of	M. O. Bullard		10	level of South River.	150	1½	40–50	— 3
16	Mount Olive, 7 miles W. of.	G. A. Casey	1901			30	1½		+ 1½
17	Newton Grove, ½ mile E. of.	R. B. Wilson	1903	155	sea level.	37	1½	16	+ 2½
18	Newton Grove, 5 miles S. of.	H. C. Gidden and A. Sutton.	1904			65	2	47	+ 3
19	Shady Grove	Shady Grove Church	1905	3	level of Little Coharie Creek.	64	2		+ 3

SCOTLAND COUNTY.

Topography.—No topographic maps have been made of any portion of this county. Railroad elevations, supplemented by field observations, seem to indicate that the surface over the southeastern half of the county is formed of the highest and oldest Pleistocene terrace plain, the Coharie plain, at elevations of perhaps 180 to 220 feet. Over the remainder of the county the surface is made up of rolling hills, being within the sandhill belt, with elevations of perhaps 230 to 400 or 500 feet. On the Coharie and Sunderland plains the streams have made but shallow incisions.

Geology.—The entire county is underlain by beds of the Patuxent formation which consist of compact arkosic sands and light drab clays. This formation rests upon basal crystalline rocks at depths of 200 to 400 feet below the surface. Over the southeastern half of the county the Patuxent beds are overlain by a surficial covering of Pleistocene sandy clays, sands, and gravels of the Coharie formation, and over the northwestern half in the sandhill area by discontinuous patches of sandy clays, sands, and gravels of the Lafayette formation.

Water Resources.—The Lafayette and Pleistocene formations furnish the greater part of the water supply which is obtained by means of open and driven wells 10 to 30 feet in depth. A few wells have been driven to depths of from 60 to 90 feet and in these the water comes from the underlying Patuxent formation. Water from the Patuxent beds may in places contain iron salts. There are no deep drilled wells in the county. At Laurinburg, in a well at Mr. Shaw's residence, a slight flow is reported to have been obtained at a depth of 90 feet, but this appears not to have been utilized.

COUNTY—CONTINUED.

Yield per minute. Flow—gallons.	Yield per minute. Pump—gallons.	How obtained at surface.	Use.	Geologic horizon and character of water-beds.	Remarks.
....	....	....	domestic.	Black Creek formation; sand.	
....	....	....	....	Black Creek formation; sand.	
....	....	....	not used.	....	
2	....	flows.	domestic.	Black Creek formation; gravel and sand.	
2	....	flows.	domestic.	Patuxent formation; micaceous sand.	
5	....	flows.	drinking.	Patuxent formation; micaceous sand.	Another horizon at 15 ft.
1	....	flows.	drinking.	Patuxent formation; sand.	Other horizons at 11-16, 23, 44 and 57 ft.

Artesian Prospects.—Abundant supplies of very soft water may be obtained from the Patuxent formation over the entire county at depths of from 50 to 300 feet. No assurance can be given that, when the water-bearing beds are tapped, the water will overflow, although it may do so at the lower levels along the streams. The most that can be expected is that the water will rise near enough to the surface to come within reach of ordinary pumps.

TYRRELL COUNTY.

Topography.—The surface of this county is very low and almost level, perhaps nowhere exceeding 12 feet above sea level. It forms a part of the Pamlico terrace plain, which is the lowest of the Pleistocene terraces. The central and southern part of the county constitutes a vast stretch of almost continuous swamp.

Geology.—Where the surface is not swampy the materials consist of fine sands, sandy loams, and clays, which are referred to the Pamlico formation. Beneath these are sands, clays, and shell marls, probably in part of Pleistocene, in part of Pliocene, and in part of Miocene age. These are not known to outcrop at the surface within the county limits.

Water Resources.—The inhabitants of this county depend in the main upon cisterns for their water supply. Many open wells 8 to 15 feet in depth are in use, however. The water from these is soft, but on account of the large content of organic matter is very unsatisfactory for household use. In many places beds of black mud occur in the Pleistocene deposits, and in open or driven wells penetrating these only nonpotable waters are obtained.

Water from depths exceeding 15 or 20 feet is as a rule hard and ferruginous. The hardness is due to the common occurrence of shell beds in the underlying strata. For this reason but few deep wells are in use. Several years ago at a mill at Alligator a well was drilled to a depth of 160 feet. Very little information is obtainable regarding it. According to one account, no water was obtained below 16 feet, but according to another some water was encountered, but was of a very unsatisfactory character. The casing was pulled up and the well abandoned. At this place no wells are in use at the present time, the water being taken from the river and distilled at the mill for boiler and domestic purposes. Wells have been drilled at Fort Landing and Columbia to depths of 48 and 61 feet respectively, but information concerning them is lacking.

In the summer of 1904 a deep well was drilled at Columbia for Mr. F. L. W. Cahoons. At a depth of 348 feet, water of a very saline character was encountered. Two or three water-bearing horizons, one of which was at a depth of 180 feet, were passed through before salty water was reached, and the water from these rose to within 2 feet of the surface. The water from these upper horizons is reported to have been good.

One assay of a water from this county is given in Table 1, pp. 502, 503, assay No. 175. This is discussed on page 491.

Artesian Prospects.—The porous sand beds of the underlying Pleistocene, Pliocene, and Miocene deposits should yield an abundance of water. Owing to the presence of beds of shell marl, the waters are likely to be hard. At depths exceeding 300 or 400 feet salty water will probably be encountered in all parts of the county. It is doubtful if flowing wells yielding potable waters are possible.

WASHINGTON COUNTY.

Topography.—The surface over the eastern half of this county is formed of the lowest and youngest Pleistocene terrace plain, the Pamlico plain, with elevations scarcely exceeding 15 feet above sea level. Much of this area is swampy. The Chowan plain covers a portion of the western half of the county, but the data available concerning it is very meager. A portion of this area is swampy, also.

Geology.—The county is underlain beneath surficial sands and loams of the Pleistocene formations by sands, clays, and marls, probably for the most part of Miocene, although possibly in part of Pliocene age. At some depth, perhaps 400 or 500 feet in the west and becoming deeper toward the east, are beds of Cretaceous age upon which the Miocene beds rest. The Pleistocene deposits which form the surface materials belong to the Chowan and Pamlico formations.

Water Resources.—Most of the water for domestic use in Washington County comes from open and driven wells 8 to 30 feet in depth, the supply being derived from the lower sandy portions of the Pleistocene deposits. Cisterns are much used at Creswell and a few are in use at Plymouth.

A considerable number of deep wells have been drilled in this county. In several instances strong flows have been obtained. From these deep sources the water is apt to be slightly hard and sulphurous. (See table of well data below.)

At Plymouth flows are obtained at about 150, 180, and 225 feet. In the town well a strong flow was obtained at a depth of 148 feet, but drilling was continued to greater depths. No other horizons were encountered, however, and the casing was pulled back to the 148-foot horizon. At Roper flows are obtained at a depth of 225 feet. In the wells of Mr. T. W. Blount at Roper shell beds were struck at 40 feet below the surface and were penetrated at intervals to the bottom of the well. This town has a fire system, the water being pumped from Mackey's Creek.

At Creswell a well was drilled for the town which is reported to have exceeded 300 feet in depth. No reliable data are obtainable concerning it. It is stated that water of an unsatisfactory quality rising to within a foot of the surface was encountered at some depth.

Assays of waters from this county are given in Table 1, pp. 502, 503, assays Nos. 176-178. These are discussed on page 491.

Artesian Prospects.—The sandy beds of the Miocene will yield an abundance of water which will in most cases be rather hard, owing to the presence of marl beds, and as a rule will be sulphurous. Potable water may be expected to depths of about 300 feet, and when the elevation at the surface is less than 10 feet above sea level flows may in many cases be obtained. At depths exceeding 300 or 400 feet the water is apt to contain considerable amounts of sodium chloride and bicarbonates.

WASHINGTON

Number.	Location.	Owner.	Date completed.	Elevation of surface above datum (feet).	Datum.	Depth (feet).	Diameter (inches).	Depth to principal water supply (feet).	Height of water, + surface (feet).
1	Plymouth	[illegible]	1902	25±	sea level.	180±	----	145	−4
2	do.	[illegible] Norman		15±	sea level.	172	2		
3	do.	[illegible]	1905	15±	sea level.	225	3		−[illegible]
4	do.	[illegible]	1905	15±	sea level.	185	2		−4
5	Plymouth, 3 miles S. of	W. F. Lucas	1905			185	2	150	−4
6	Roper	T. W. Brown	1903	10	sea level.	225+	2	225	−[illegible]
7	do.	John L. Roper Lumber Co.	1903	11	sea level.	225	2	216	−[illegible]
8	Mackeys Ferry, 2½ miles N. of.	C. W. Brown	1903	15±	sea level.	200	2	200±	−[illegible]
9	do.	do.	1903	15±	sea level.	193	2	193	−2
10	do.	do.		15±	sea level.	140	2		
11	do.	do.		15±	sea level.	200±	2	190±	6

WAYNE COUNTY.

Topography.—The surface of this county is formed of three Pleistocene terrace plains. Owing to the lack of topographic maps over all but the northern one-fourth of the area, their detailed distribution is but imperfectly known. The Wicomico plain forms a belt several miles wide along Neuse River at elevations of perhaps 70 to 80 feet above sea level. The Sunderland plain covers most of the surface to the north of Neuse River and a portion of the southeastern part of the county, at elevations of 110 to 150 feet. The highest or Coharie plain forms the surface of much of the southwestern part of the county, with probable elevations of 160 to 190 feet. These two latter are considerably dissected by stream erosion. The plains are separated from each other in places by well-defined escarpments.

Geology.—The northwestern part of the county is closely underlain by ancient slate rocks which appear at the surface along Little River and at various other places. Their upper surface dips to the southeast and passes below water level. The Patuxent formation, consisting of arkosic sands and drab, compact clays, rests upon the uneven surface of the slate. The beds of this formation do not rise much above water level in Neuse River, and southeast of Goldsboro they pass finally beneath low-water level. The laminated sands and clays of the Black Creek formation rest upon the Patuxent beds unconformably. These

COUNTY.

Yield per minute.		How obtained at surface.	Use.	Geologic horizon and character of water-beds.	Remarks.
Flow—gallons.	Pump—gallons.				
8	....	flows.	public.	Miocene.	Flows in pit 4 ft. below surface. See water assay No. 176, table 1, pp. 502, 503.
4	....	flows.	domestic.	Miocene.	
4?	....	....	domestic.	Miocene.	Another horizon at 140 ft.
....	....	....	domestic.	Miocene.	Flows in pit 4 ft. below surface. Three other wells, all about same depth.
....	....	pump.	....	Miocene; limestone.	
5	....	flows.	domestic.	Miocene; sand and shells.	See water assay No. 178, table 1, pp. 502, 503.
6	....	flows.	public.	Miocene; sand.	Another horizon at 80 ft. Flows in pit below surface.
....	....	....	....	Miocene; sand between two rock layers.	
....	....	pitcher pump.	drinking.	Miocene; rock.	Another horizon at 150 ft.
....	....	....	....	Miocene.	
....	....	pump.	....	Miocene; shell-rock.	

underlie practically all of the county, but in about the northwestern half of the area exist merely as a relatively thin sheet transgressing westward over the Patuxent beds. South of Neuse River Eocene limestones are present, filling disconnected basins in the eroded Black Creek surface. Over a portion of the northern part of the county Miocene sands and clays rest directly upon the Black Creek formation. Spread over all older formations is a surficial covering of Pleistocene terrace deposits consisting of sandy clays, sands, and gravels. These are referred to the Coharie, Sunderland, and Wicomico formations.

Water Resources.—The sandy and gravelly base of the Pleistocene terrace deposits offers an abundant source of soft water for domestic use over the greater part of the area. It is obtained by means of shallow open and driven wells 10 to 30 feet in depth. In the northwest there are many open wells which have been sunk through the surface deposits into the underlying slate rock to depths of 20 or 25 feet.

Many springs occur along the river bluffs at the contact of the lower sandy portions of the Pleistocene beds with the underlying, less pervious, older formations. There are also many springs in other parts of the county, which come from the Pleistocene deposits. A spring belonging to Mr. N. S. Perkins and known locally as the Perkins Spring is situated in the level bottom of a small valley about 1 mile from Pikeville. It has a flow of approximately 3 gallons per minute, the water probably issuing from the lower sandy portion of the Pleistocene de-

posits. The water is sold to some extent in the vicinity of Pikeville and in Goldsboro. A small amount of iron oxide has been deposited in the channel leading from the stream.

It is stated that the water of a large spring near Fremont is sold locally.

At Seven Springs there are a number of springs in close proximity to each other issuing from Black Creek beds near the base of a high escarpment. These, seven in number, have been walled up and roofed over and are kept in convenient order for the use of guests at the hotel. The property is owned by the Goldsboro Seven Springs Security Company of Goldsboro, N. C., which has been conducting the place as a health resort. Medicinal properties are ascribed to the waters of the several springs. Analyses have been made of these waters. (See Table 2, analyses 51-57, pp. 508, 509.)

One-half mile above Seven Springs are two other similar springs known as the "ninth" and "tenth" springs, respectively. A hotel is located here, also, medicinal properties having been ascribed to the water. This property is owned by Mrs. Fannie B. Ham. Water from both the "seven springs" and from the "ninth" and "tenth" springs has been bottled and sold to a limited extent.

At Goldsboro the waterworks plant is owned by the city. The water is obtained from Little River. It is very soft, containing on an average of 60 parts per million of total solids.

A number of deep wells have been drilled in the county, some of which enter the underlying basement rocks. For a partial list of those concerning which information has been obtained, see table of well data below.

At Goldsboro three wells have been drilled through the deposits of the Coastal Plain into the underlying basement rocks, the deepest, that of the Borden Manufacturing Company, attaining a depth of 807 feet. The rock surface beneath Goldsboro is apparently quite uneven, wells within short distances of each other upon the level plain upon which the town is situated entering the basement rocks at widely varying depths. The water-bearing beds of the Coastal Plain deposits have been cased off in all of these wells. The basement rocks yield a hard, alkaline water, rising within 30 to 50 feet of the surface, and on pumping yield supplies of from 20 to 85 gallons per minute.

Flowing wells have been obtained from the Patuxent formation on the farm of Mr. E. B. Borden, about 1½ miles northwest of Goldsboro. There are 3 wells, each about 35 feet in depth and having about the same flow. A measurement of the flow of the well at the house gave

$1\frac{1}{5}$ gallons per minute. These wells are situated on the Wicomico terrace bordering Neuse River. A few other flows have been obtained in the vicinity of Goldsboro upon this lower level. In the town of Goldsboro there are many drilled wells 35 to 50 feet in depth which tap Patuxent horizons. In these the water rises to within 10 to 12 feet of the surface.

A number of wells have been drilled at Mount Olive and in the surrounding country to depths ranging from 30 to 150 feet, which probably obtain their supply from the Black Creek formation. Some of these, located in valleys a few feet below the general level, are flowing wells.

Assays and analyses of waters from this county are given elsewhere in this report, as follows: Table 1, pp. 192, 193, assays Nos. 179-185; Table 2, pp. 508, 509, analyses Nos. 51-57. These are discussed on page 491.

Artesian Prospects.—The ancient basement rocks which underlie the deposits of the Coastal Plain yield fair supplies of potable water at various depths down to 600 or 800 feet. The Patuxent beds which rest upon the slates offer a possible source of excellent water over the entire county. Over the northwestern two-thirds of the county these are reached at moderate depths, but towards the southeast they pass deeper beneath the Black Creek formation, and in the extreme southeast their upper surface probably lies at a depth of about 300 feet. In the south and southeast at depths of 50 to 300 feet the Black Creek formation which rests upon the Patuxent formation will yield from its contained sand beds fair supplies of potable water which in some localities is rather high in iron salts. The Eocene and Miocene beds are unimportant as water-bearers, except locally.

WAYNE

Number.	Location.	Owner.	Date completed.	Elevation of surface above datum—feet.	Datum.	Depth—feet.	Diameter—inches.	Depth to principal water supply—feet.	Height of water, ± surface—feet.
1	Dobbersville	J. F. Hollingsworth	1900	......	....	90	1¼	....	— 3
2	Fremont	Town	1901	145	sea level.	176	3	....	—20?
3	....do	Fremont Oil Mill	1903	140±	sea level.	190	4½	....	—25?
4	....do	....do	1906	140±	sea level.	140	6	....	......
5	....do	J. D. Davis	1966	144	sea level.	140	4	....	— 4½
6	....do	W. T Turlington	1901	144	sea level.	126	....	....	—10
7	Goldsboro	Borden Manufacturing Co.	1906	110±	sea level.	807	6	....	—50
8	....do	Goldsboro Ice Co.	about 1890.	110	sea level.	266	8	....	—30
9	....do	J. M. Grantham	1905	......	sea level.	75	1¼	....	+ 5
10	Goldsboro, 1½ miles N. W. of.	E. B. Borden	......	......	....	35	3	....	+ 0
11	Goldsboro, 1¾ miles W. of	State Hospital	1895	20	level of Neuse River.	570	6?	....	—20
12	Goldsboro, 3 miles N. E. of	H. D. Ham	1905	......	....	60	2	....	+ 5
13	Mount Olive, 3 miles N. E. of.	William Potts	1900	......	....	30	1¼	....	+ 6
14	Mount Olive, 1¾ miles N. of	Louis Lambert	1906	......	....	85	1¼	....	— 6
15	Mount Olive, 1½ miles N. W. of.	W. J. Flowers	1905	......	....	43	1¼	....	+ 2½
16	Mount Olive, 2½ miles N. W. of.	Asher Flowers	1905	......	....	44	1¼	....	+ 3
17	Mount Olive, 3 miles W. of	D. L. Flowers	1896	......	....	151	1¼	....	—15
18	Mount Olive, 2½ miles W. of	Elias Flowers	1900	......	....	104	1¼	....	—38
19	Mount Olive, 1 mile W. of	M. McPhail	......	......	....	80	1¼	....	+ 2
20	Mount Olive, 2½ miles N. E. of.	M. B. Farmer	1897	......	....	80?	1¼	....	+ 8?

WILSON COUNTY.

Topography.—The Sunderland terrace plain of the Pleistocene forms the surface over the greater part of the county at elevations of 110 to 150 feet. This plain is considerably dissected by streams. The highest or Coharie plain has a limited development in the western part of the county at elevations ranging from 180 to 230 feet. The Wicomico plain, which is the next lower than the Sunderland plain, has a limited development along Contentnea Creek at elevations of 90 to 100 feet; while the Chowan plain, still lower, at elevations of 50 to 80 feet, extends up the valley of Contentnea Creek as a bordering terrace to and several miles beyond Woodard Bridge.

Geology.—Over the western half of the county basement rocks are exposed in the beds of the streams. Their uneven surface dips to the

COUNTY.

Yield per minute.		How obtained at surface.	Use.	Geologic horizon and character of water-beds.	Remarks.
Flow—gallons.	Pump—gallons.				
				Black Creek formation?	
				basement rock.	Entered basement rock at 100 ft.
	20			basement rock.	Entered basement rock at 105 ft.
				basement rock.	
				basement rock.	Entered basement rock at 90 ft.
				basement rock.	Entered basement rock at 100 ± ft.
	25			basement rock.	Entered basement rock at 268 ft. Supply not sufficient and well not used.
	50			basement rock.	Entered basement rock at 175 ft. See sec. Bull. U. S. G. S. 138, pp. 200–203.
5				Patuxent formation.	
$1\frac{1}{5}$				Patuxent formation; sand.	See assay No. 180, table 1, pp. 502, 503. Has two other wells similar to this.
	84			basement rock.	Entered basement rock at about 100 ft.
1				Patuxent formation; gravel.	
		flows.		Black Creek formation; blue sand.	
				Black Creek formation; sand.	
6		flows.		Eocene? greenish glauconitic sand.	See water assay No. 184, table 1, pp. 502, 503.
5		flows.		Black Creek formation? gravel.	See water assay No. 185, table 1, pp. 502, 503.
				Black Creek formation; sand.	Penetrates about 138 ft. of the Eocene limestone. See water assay No. 182, table 1, pp. 502, 503.
				Black Creek formation; sand and gravel.	
4		flows.		Black Creek formation; sand.	
7		flows.		Black Creek formation; coarse sand.	

eastward, and on Contentnea Creek passes finally below water level about 2 miles below Roundtree bridge. The depth of these rocks beneath the surface in the eastern part of the county is not known, but it probably does not exceed 150 or 200 feet. Over about the eastern one-third of the county the Patuxent formation, consisting of arkosic sands and drab, compact clays, rests upon the basal crystallines. These rise but little above water level along Contentnea Creek. Beds of Miocene age rest upon the Patuxent formation and overlap westward upon the crystallines to a little beyond Wilson. Pleistocene terrace deposits form a surface covering over all older formations. These are referred to the Coharie, Sunderland, Wicomico, and Chowan formations.

Water Resources.—The chief supply of water for domestic use is derived from the basal sandy and gravelly beds of the Pleistocene forma-

tions by means of open and driven wells 10 to 30 feet in depth. The Pleistocene materials are in most places so compact that no curbing is required. In the western part of the county a few dug wells 40 to 60 feet in depth penetrate the upper, decomposed portion of the basement rocks from which supplies are obtained. Springs are common, and where occurring conveniently are used for domestic purposes.

About 2 miles north of Wilson, at the head of a small spring-fed valley, a feeder of Toisnot Swamp, are Young's Park Springs, the water from which is sold in Wilson. The springs are three in number, and have a flow estimated at about 2 gallons per minute.

The waterworks plant at Wilson is owned and operated by the town. The supply is obtained from Toisnot Swamp, 2 miles directly north of the courthouse. The plant was installed in 1892 and additions were made in 1908. The pumping is accomplished by means of two electrically driven triplex pumps having capacities of 500,000 gallons per day each. A pressure filter made by the New York Continental Jewel Filtration Company, having a capacity of 2,000,000 gallons per day, is in use. Besides being filtered, the water is also treated chemically. A maximum direct pressure of 100 pounds per square inch is possible. Chemical analysis of the unfiltered water shows that it is soft, with an excess of organic matter, the latter being derived from the vegetable matter in the swamp through which the water passes.

In the sand and gravel layers of the Miocene which underlie the town, water is obtained down to bedrock by means of wells 90 to 100 feet in depth.

Several deep wells have been drilled into the granite which underlies Wilson at from 90 to 120 feet below the surface, the deepest being to a depth of 216 feet. An abundant supply of water is obtained from crevices in the granite. (See assays, Table 1, of water from wells of the Clark Plate Ice Company and Pepsi-Cola Bottling Company.) The water rises to within 12 to 14 feet of the surface. When at a depth of about 120 feet the well of the Pepsi-Cola Bottling Company overflowed at the surface, but the flow was lost when the next crevice was struck. The flow was probably due to the tapping of a small reservoir in which the water was under pressure.

In the southeastern part of the county, near Stantonsburg and Moyeton, there are several flowing wells located on low land along Contentnea Creek whose elevation above the sea is about 50 or 60 feet. The flows, which amount to from 3 to 25 gallons per minute, are obtained from a horizon in the Patuxent formation at a depth of about 90 feet below the surface.

A.—Deep well of the Clarendon Waterworks Company, Wilmington, N. C., flowing highly saline water from Upper Cretaceous strata.

B.—The waterworks plant at Wilson, N. C.

Assays and one analysis of waters from this county are given elsewhere in this report, as follows: Table 1, pp. 502, 503, assays Nos. 186-188; Table 2, pp. 508, 509, analysis No. 58. These are discussed on page 491.

Artesian Prospects.—The crystalline rocks which underlie the county are a possible source of potable water to depths of several hundred feet below the surface.

The principal source of artesian water from the deposits of the Coastal Plain is the Patuxent formation, which occurs only in the southeastern part of the county. Flowing wells may be obtained from Patuxent horizons, on the lowlands in the southeast along Contentnea Creek and its tributaries.

The Miocene beds overlying the Patuxent formation, while in many places containing abundant supplies, will in most places yield a hard water, due to the presence of shell beds.

WILSON

Number.	Location.	Owner.	Date completed.	Elevation of surface above datum—feet.	Datum.	Depth—feet.	Diameter—inches.	Depth to principal water supply—feet.	Height of water, + surface—feet.
1	Wilson	Pepsi-Cola Bottling Co.	1905	140	sea level.	200	4	140	—10
2	....do	Clark Plate Ice Co.	1906	140	sea level.	216	4		—16
3	....do	County	1906	140	sea level.	138	4		
4	....do	J. S. Woodard		140	sea level.	90	4		
5	....do	....do		140	sea level.	170	4		
6	....do	J. F. Farmer	1907	140	sea level.	105	6		—15
7	Wilson, 5 miles S. E. of	L. P. Woodard	1907	120	sea level.	238	4		—50
8	Wilson, 1 mile S. E. of	W. P. Singletary	1905	134	sea level.	140	4	110	— 6
9	Wilson, 2 miles S. E. of	J. D. Farrior		120	sea level.	150	4		
10	Wilson, 5 miles S. E. of	W. J. Davis		100	sea level.	90	1½	90	— 8
11	Stantonsburg, 1 mile E. of.	S. H. Crocker	1905	60	sea level.	90	1½	90	+ 1
12	Stantonsburg, 2 miles W. of	....do	1905	60	sea level.	96	1½	90	+ 2
13	Stantonsburg, ½ mile S. W. of.	....do	1905	60	sea level.	50	1½	50	+ 0
14	Moyeton, 1 mile E. of	B. J. Thompson	1905	59	sea level.	96	1½	96	+ 0

COUNTY.

Yield per minute. Flow—gallons.	Yield per minute. Pump—gallons.	How obtained at surface.	Use.	Geologic horizon and character of water-beds.	Remarks.
....	50	pump and gasoline engine.	soft drinks.	basement rock.	Entered basement rock at 90 ft. See water assay No. 188, table 1, pp. 502, 503.
....	35	steam pump.	manufacture of ice.	basement rock.	See water assay No. 187, table 1, pp. 502, 503.
....	....	....	....	basement rock.	Other horizons at 12 and 120 ft.
....	....	....	....	Miocene?	
....	....	....	....	basement rock.	
....	....	hand force pump.	drinking.	basement rock.	Entered basement rock at 50 ft.
....	....	force pump.	....	basement rock.	Entered basement rock at 200 ft.
....	....	force pump.	domestic.	basement rock.	Entered basement rock at 75 ft.?
....	....	....	....	Patuxent formation.	Basement rock struck at 90 ft.
....	....	pump.	....	....	
3	....	flows.	domestic.	Patuxent formation; sand.	Another horizon at 12 ft.
3	....	flows.	domestic.	Patuxent formation; sand.	Another horizon at 14 ft.
3	....	flows.	domestic.	Patuxent formation; sand.	Another horizon at 15 ft.
25+	....	flows.	domestic.	Patuxent formation; sand.	Another horizon at 15 ft.

CHAPTER II.

THE QUALITY OF SOME WATERS OF THE COASTAL PLAIN OF NORTH CAROLINA.

By HORATIO N. PARKER.

INTRODUCTION.

The available information on the chemical composition of the ground waters of North Carolina is so small that no general statements can be presented concerning the quality of the waters likely to be encountered over extensive areas, and discussion has necessarily been limited to the characteristics of the comparatively few samples that have been tested. The results are given in two tables, the first including field assays, and the second more detailed analyses. The field assays were made by L. W. Stephenson and B. L. Johnson according to the methods outlined in Water-Supply Paper, U. S. Geological Survey, No. 151, and the results obtained may be considered approximate in character. A part of the detailed analyses were performed by J. R. Evans, in the branch laboratory of the U. S. Geological Survey at the University of Georgia, Athens, Ga., on samples collected by B. L. Johnson, of the U. S. Geological Survey, during the progress of field investigations. The remaining analyses, performed by several analysts and procured from various sources, have been recomputed to ionic form in parts per million in order that the data may be easily compared.

DISCUSSION OF ANALYSES.

BEAUFORT COUNTY.

The five chemical analyses, 1 to 5, Table 2, show waters that differ considerably. Analysis 1 indicates a sodic, calcic, alkaline water; analysis 2, a calcic, alkaline water of great temporary hardness; analysis 3, a sodic, alkaline water very suitable for laundering; analysis 4, a calcic, alkaline, saline water; and analysis 5, a soft, magnesic, alkaline, saline water.

The assays of Beaufort County waters are recorded in Table 1. Assays 2, 4, and 5 indicate waters very high in carbonates; assays 7, 8, and 9 show waters with less carbonates; and assay 3 denotes a water tolerably high in chlorides and carbonates; assay 6 shows a remarkably soft water. Most of these waters that were assayed have considerable color and little or no sulphates.

BERTIE COUNTY.

The only water tested from Bertie County was from the flowing well at Windsor. From the analysis, which appears in Table 2, this water may be classed as sodic alkaline saline.

BLADEN COUNTY.

The only analysis that was made of Bladen County water is presented in Table 2; it shows a very soft water.

The results of the assays of water from this county appear in Table 1. Assays 10, 12, 16, 17, 19, 21, and 22 show remarkably soft water. Assays 13, 14, 15, and 16 denote waters moderately high in carbonates. Assay 20 is a test of a water of somewhat high carbonates and chlorides. None of the waters of this county have more than a trace of sulphates.

BRUNSWICK COUNTY.

The results of the chemical analyses of the water of Brunswick County appear in Table 2. Analyses 8 and 9 record tests of salty waters at Fort Caswell that are unlike. Analysis 8 shows a highly mineralized sodic chloride water, and analysis 9 shows an even more highly mineralized water that may be classed as sodic calcic alkaline saline. Analyses 10 to 23 are tests of samples of water that were collected at intervals from a deep well at the Quarantine Station during 66 minutes' pumping. Analysis 10 shows the composition of water that probably had been standing in the well since it was last pumped. This water is soft and not high in chlorides. The samples taken 3 and 6 minutes later are very high in chlorides and show, also, an increase in carbonates. Samples taken thereafter for 35 minutes at 5-minute intervals show steady diminution in carbonates and chlorides. Samples taken in the succeeding half hour were fairly constant in composition, for the carbonates and chlorides fluctuate but little. These tests may be compared with assays 26 and 27, Table 2.

The assays of Brunswick County waters appear in Table 1. Assays 23 and 24 are tests of two saline waters, one of which comes from a deep and the other from a shallow well. The two waters are highly mineralized, large quantities of carbonates, sulphates, and chlorides being present. Assays 25 and 28 indicate waters moderately high in carbonates and low in chlorides.

CARTERET COUNTY.

No mineral analyses were made of the waters of Carteret County, but seven assays are recorded in Table 1. Assays 30, 31, and 32 indi-

cate soft waters. Assays 29 and 33 show waters high in carbonates, while assays 34 and 35 are tests of waters that carry carbonates in moderate amounts. All of the Carteret County waters that were tested have considerable color, are low in chlorides, and carry little or no sulphates.

CHOWAN COUNTY.

Analysis 24, Table 2, is a test of the city water at Edenton and indicates a sodic calcic alkaline water. Assay 36, Table 1, shows a water of low temporary and permanent hardness.

COLUMBUS COUNTY.

Analysis 25, Table 2, shows a very soft calcic sodic alkaline water. Assays 42, 44, and 46 are tests of waters from shallow wells. Of these assays the first two denote very soft waters, but the last indicates a moderate amount of carbonates. Assays 37, 39, and 41 are tests of waters which rise in the wells but are not under sufficient hydrostatic pressure to overflow. These waters differ considerably in character. Assay 37 indicates a water moderately high in carbonates; assay 39, one very high in carbonates and high in chlorides, and assay 41, a soft water. Assays 38, 40, 43, 45, 47, 48, 49, 50, and 51 are tests of the waters of flowing wells. Of these assays, 43, 45, 47, 48, and 50 show waters low in chlorides and moderately high in carbonates; assay 49 indicates a water high in carbonates and low in chlorides; assay 40, a water high in chlorides and low in carbonates; and assay 38, a very soft water, low in both carbonates and chlorides. None of these Columbus County waters carry more than a trace of sulphates, but all of them contain a little iron.

CRAVEN COUNTY.

Analysis 26, Table 2, shows a calcic sodic alkaline saline water. Assay 58, Table 1, indicates a very soft water that is high in chlorides. Assays 53 and 60 are tests of waters carrying carbonates in moderate amounts, while assays 54 and 59 are those of waters high in carbonates. The other assays indicate waters low in carbonates. All of the assays of the Craven County water, except 58, show low chlorides, and none of them indicate more than a trace of sulphates. Many of the waters have a noticeable amount of color.

CUMBERLAND COUNTY.

No mineral analyses of Cumberland County waters are presented. Assay 65 shows a water very low in carbonates, high in sulphates, and with a considerable amount of chlorides. Assay 72 indicates a water

carrying a moderate amount of carbonates and high sulphates. Assays 68, 69, and 70 indicate waters high in carbonates, and with no sulphates. Of these three assays, 68 shows more chlorides than the others. The rest of the assays denote very soft water. Sulphates are wanting in all of the Cumberland County assays except in 65 and 72.

CURRITUCK COUNTY.

Assay 74, Table 1, is the only test that was made of a Currituck County water. It shows one that is very soft.

DARE COUNTY.

But two tests were made of the waters of Dare County. Analysis 27, Table 2, shows a very soft sodic saline water, and a very soft one is also shown by assay 75, Table 1.

DUPLIN COUNTY.

No mineral analyses were made of the waters of Duplin County, but assays were made of several waters, and the results obtained are recorded in Table 1. Assays 77 and 80 show very soft waters that carry rather more chlorides than most of the Duplin County waters that were tested. Assay 78 indicates a water moderately high in carbonates, and high in chlorides. The other waters are all moderately high in carbonates and low in chlorides. None of the Duplin County waters carried more than a trace of sulphates.

EDGECOMBE COUNTY.

No mineral analyses were made of the waters of Edgecombe County. The results of the tests made by assay appear in Table 1. Assays 85 and 87 indicate very soft waters, while assays 86 and 88 show waters moderately high in carbonates. No sulphates were shown in Edgecombe County waters.

GATES COUNTY.

No mineral analyses were made of the waters of Gates County, but one water was tested by assay. This assay, 89 of Table 1, indicates a very soft water.

GREENE COUNTY.

No mineral analyses were made of the waters of Greene County, but two waters were tested by assay, and the results appear in Table 1. Assay 90 shows a very soft water and assay 91 a water that is moderately high in carbonates. Both waters are low in sulphates.

HALIFAX COUNTY.

Analyses 28, 29, and 30, Table 2, show very soft waters. Assays 92, 94, and 95, Table 1, are tests of waters that are somewhat high in carbonates. Assay 93 indicates a water soft but rather high in chlorides. All four waters are low in sulphates. Distinct color was shown in the three waters whose color was read.

HARNETT COUNTY.

No mineral analyses were made of the waters of this county and but two waters were tested by assay. Assay 96, Table 1, shows a water moderately high in carbonates, and assay 97 one that is very soft. In both waters the sulphates and chlorides are low.

HERTFORD COUNTY.

Analyses 31, 32, and 33, Table 2, and assay 98, Table 1, all show very soft waters.

HYDE COUNTY.

Analysis 34, Table 2, shows a highly mineralized sodic magnesic alkaline saline water. Analysis 35, Table 2, denotes a very soft sodic alkaline water which would be excellent for laundering, but which might foam in steam boilers. Assays 99 and 100, Table 1, indicate waters carrying high carbonates, no sulphates, and rather high chlorides.

JOHNSTON COUNTY.

Analysis 36, Table 2, and assays 103 and 104, Table 1, show remarkably soft waters. The waters tested by assays 101 and 102 are also soft, but they are somewhat more highly mineralized than the other Johnston County waters of which tests were made.

JONES COUNTY.

No analyses were made of Jones County waters; the assays are recorded in Table 1. Assay 105 indicates a very soft water; assays 106, 107, and 108 denote waters moderately high in carbonates and with little or no sulphates. Assay 107 shows more chlorides than the other assays of waters in this county.

LENOIR COUNTY.

Analysis 37, Table 2, shows a soft magnesic sodic alkaline water, and analysis 38 a very soft sodic alkaline water. Assays 111, 112, and 113, Table 1, indicate very soft waters, while assays 109 and 110 denote waters which, though soft, carry more carbonates.

MARTIN COUNTY.

No mineral analyses of the waters of this county were made and but one water was tested by assay. This water, assay 114, Table 1, is very soft.

MOORE COUNTY.

Only one mineral analysis (39, Table 2) and two water assays (115, 116, Table 1) were made of the waters of this county. All show remarkably soft waters.

NASH COUNTY.

No mineral analyses were made of the waters of Nash County, and but two assays. These are assays 117 and 118, Table 1, both showing remarkably soft waters.

NEW HANOVER COUNTY.

Analysis 40, Table 2, is a test of the highly mineralized sodic calcic alkaline saline water from the flowing well of the Clarendon Waterworks Company. Analysis 41 shows a calcic sodic alkaline water of moderate temporary hardness. The assays appear in Table 1. Assay 119 indicates a ferruginous water, high in carbonates, without sulphates, and low in chlorides. Assay 120 is of a water high in carbonates, but low in sulphates and chlorides. Assay 121 shows a water high in carbonates, with a noticeable amount of chlorides and little sulphates.

Assays 122 to 135 are tests of waters in Wilmington. Assays 123 and 128 show strongly mineralized waters, high in chlorides, sulphates, and carbonates. Assays 124, 125, 126, 127, 135, and 136 indicate soft waters. Assays 129, 130, 132, and 134 denote waters low in chlorides, moderately high in carbonates, and carrying no sulphates. Assays 122 and 131 denote waters that are moderately high in carbonates and carry noticeable amounts of sulphates and chlorides. Assay 137 is a test of a water that carries no sulphates, an appreciable amount of chlorides, and moderately high carbonates.

NORTHAMPTON COUNTY.

No mineral analyses of the waters of Northampton County were made, but two assays are recorded in Table 1. Assay 138 indicates an extremely soft water; assay 139 a water that contains rather more carbonates than the other. Neither water contains more than a trace of sulphates.

ONSLOW COUNTY.

Analysis 42, Table 2, assays 140, 143, and 144, Table 1, show very soft waters. Assay 141 indicates a water very high in carbonates, while assay 145 shows one carrying carbonates in only moderate amounts. All of these waters are low in sulphates and chlorides.

PAMLICO COUNTY.

No mineral analyses were made of the waters of Pamlico County; the assays are recorded in Table 1. Assays 146, 148, and 150 all indicate very soft waters. The high color shown by assay 150 is noteworthy. Assay 149 and 151 denote waters that are soft, but are rather higher in carbonates than the three preceding. Assays 147 and 152 show waters carrying very high carbonates. The chlorides and sulphates in the Pamlico County waters are low.

PENDER COUNTY.

No mineral analyses of the waters of this county were made. Three waters were tested by assays, the results of which are recorded in Table 1. Assay 153 shows a water high in carbonates and chlorides, but low in sulphates; assay 154 indicates a very soft water; and assay 155 one that is high in carbonates, but low in sulphates and chlorides.

PITT COUNTY.

Analysis 43, Table 2, shows a sodic alkaline water that is excellent for laundry use. Assays 156 and 159, Table 1, show very soft waters. The other assays of Pitt County waters show moderate amounts of carbonates. All of the waters of the county that were tested show low sulphates and chlorides and have a noticeable amount of color.

RICHMOND COUNTY.

Analysis 49, Table 2, and assay 163, Table 1, show remarkably soft waters.

ROBESON COUNTY.

Analyses 44 to 48, Table 2, show the quality of the waters of Red Springs. The waters are not highly mineralized, but they carry considerable iron. Analysis 47 indicates a water differing from the others, the content of potassium shown being higher. Assays 164 to 167, Table 1, indicate water carrying no sulphates, low chlorides, and moderate amounts of carbonates.

SAMPSON COUNTY.

Analysis 50, Table 2, shows a soft calcic alkaline water. Assays 173 and 174, Table 1, indicate very soft waters. Assay 170 shows a water that contains moderately high carbonates and chlorides. Assay 172 indicates considerable iron and rather high carbonates. The other assays of the waters of Sampson County show moderate amounts of carbonates and low chlorides. All of the waters in the county that were tested carry little or no sulphates.

TYRRELL COUNTY.

No mineral analyses of the waters of Tyrrell County were made, and there is but one assay—175, Table 1. This assay indicates a remarkably soft water.

WASHINGTON COUNTY.

No mineral analyses of the waters of Washington County are presented. Three tests were made by assay, and the results of these are recorded in Table 1. Assays 176 and 178 indicate waters very high in carbonates, and assay 177 shows a water in which the carbonates are present in only moderate amount. All three of these waters contain a trace of sulphates and considerable amounts of chlorides.

WAYNE COUNTY.

Analyses 51 to 57, Table 2, show the composition of the waters of the Seven Springs; the waters are very soft and contain appreciable amounts of iron. The results of tests of other Wayne County waters are shown by assays 179 to 185, Table 1. All of the waters are remarkably soft, except possibly that tested by assay 182, which shows higher carbonates than the other assays.

WILSON COUNTY.

Analysis 58 shows a soft sodic alkaline water very suitable for laundry work. Assay 186 indicates a remarkably soft water, while assays 187 and 188 show waters moderately high in carbonates. All of the waters of this county that were tested are low in chlorides and contain not more than a trace of sulphates.

TABLE 1—ASSAYS OF NORTH CARO

[Parts per

No.	Date.	Source.	Depth in feet.	Color.	Iron (Fe).
		BEAUFORT COUNTY—			
1	Oct. 13, 1906	Aurora, 2 miles south of, well of Bennett & Leach at Bennett's Camps.	140	0	trace.
2	Oct. 17, 1906	Bath, flowing well of T. A. Brooks	121	57	trace.
3	Oct. 17, 1906	Bath, well of J. S. Marsh	16	57	0
4	Oct. 15, 1906	Blounts Creek, well of S. R. Fowle & Son	87	66	trace.
5	Oct. 13, 1906	Idalia, flowing well of H. B. Bell	204	17	0
6	Oct. 19, 1906	Minneola, shallow well near	22	0	0
7	Oct. 19, 1906	Washington, flowing well of J. J. Woolard	32	35	trace.
8	Oct. 17, 1906	Washington, well of Washington Investment Co.	57	22	--------
9	Oct. 19, 1906	Wharton, flowing well of C. C. Williams	40	17	--------
		BLADEN COUNTY—			
10	Oct. 23, 1906	Bladenboro, flowing well of S. N. Ferguson	50	--------	3
11	Oct. 23, 1906	Bladenboro, flowing well of Bridger & Co.	15	--------	3
12	Oct. 23, 1906	Bladenboro, well of Bridger & Co.	52	--------	trace.
13	Oct. 22, 1906	Clarkton, well of G. W. Hester	92	--------	trace.
14	Oct. 22, 1906	Clarkton, well of O. L. Clark, 100 ft. southwest of railroad	218	--------	trace.
15	Oct. 22, 1906	Clarkton, well of O. L. Clark, 200 yds. southwest of railroad	227	--------	trace.
16	Nov. 6, 1906	Elizabethtown, spring of Irwin Robinson	0	--------	trace.
17	Nov. 6, 1906	Elizabethtown, well of G. W. Hall	25–30	--------	trace.
18	Oct. 21, 1906	Emerson, well of Porter, 100 ft. northeast of railroad	110	--------	1
19	Oct. 21, 1906	Emerson, well of Porter, 200 ft. west of railroad	15	--------	1
20	Nov. 16, 1906	Point Caswell, 3 miles west of, flowing well of Frank Sessoms on west bank of Black River.	98	--------	trace.
21	Oct. 21, 1906	Rosindale, well of Mrs. D. J. Clark, 200 ft. west of railroad	10	--------	trace.
22	Oct. 21, 1906	Rosindale, well of A. A. Clark, 300 yards northeast of railroad	0	--------	1
		BRUNSWICK COUNTY—			
23	Oct. 17, 1906	Fort Caswell, well of U. S. Government	800	--------	32 1
24	Oct. 17, 1906	Fort Caswell, well of U. S. Government	16	--------	1.2
25	Oct. 17, 1906	Southport, well of Kate Stuart	20–25	--------	trace.
26	Oct. 19, 1906	Southport, well of U. S. Government Quarantine Station	400	--------	1.5
27	Oct. 19, 1906	Southport, well of U. S. Government Quarantine Station	400	--------	1
28	Oct. 17, 1906	Southport, public well in grove	103	--------	3
		CARTERET COUNTY—			
29	Sept. 11, 1906	Beaufort, flowing well at oyster fishery	235	22	trace.
30	Sept. 10, 1906	Beaufort, well of H. D. Noe	20	83	--------
31	Sept. 11, 1906	Harker's Island	30	78	1
32	Sept. 10, 1906	Morehead, well of J. B. Morton	10	22	0
33	Sept. 10, 1906	Morehead, deep well of R. W. Taylor	288	61	trace.

*Trace signifies less than 35 parts per million. †Zero signifies less than 5 parts per million.

LINA COASTAL PLAIN WATERS.

Million.]

Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Analyst.	Remarks.
....	trace.*	20	B. L. Johnson.......	Odor of H_2S.
386	trace.	15	B. L. Johnson.......	do.
199	trace.	176	B. L. Johnson.......	In quicksand and under clay.
448	0†	15	B. L. Johnson.......	Deepest well in city and on highest land.
373	trace.	20	B. L. Johnson.......	Odor of H_2S.
....	0	20	B. L. Johnson.......	From sand, under at least 12 ft. of mottled yellow clay.
199	trace.	15	B. L. Johnson.......	
187	trace.	15	B. L. Johnson.......	
261	0	14	....	
....	0	10	B. L. Johnson.......	
124	0	14	B. L. Johnson.......	
50	0	14	B. L. Johnson.......	
211	0	19	B. L. Johnson.......	
149	0	9	B. L. Johnson.......	Strong odor of H_2S.
149	0	14	B. L. Johnson.......	
12	0	19	L. W. Stephenson...	Probably Cretaceous—Lafayette contact.
75	trace.	29	L. W. Stephenson...	
199	trace.	19	B. L. Johnson.......	
....	0	19	B. L. Johnson.......	
323	0	129	L. W. Stephenson...	
....	0	24	B. L. Johnson.......	
....	0	19	B. L. Johnson.......	
349	256	8,115	B. L. Johnson.......	
378	460	6,021	L. W. Stephenson...	
140	trace.	44	B. L. Johnson.......	
398	....	8,374	L. W. Stephenson...	SO_4 greater than 626. First water drawn after well had been standing.
249	43	298	L. W. Stephenson...	After pumping 20 minutes.
249	0	24	L. W. Stephenson...	
331	0	14	B. L. Johnson.......	Odor of H_2S.
62	trace.	63	B. L. Johnson.......	
12	0	30	B. L. Johnson.......	
62	trace.	50	B. L. Johnson.......	
360	0	15	B. L. Johnson.......	

TABLE 1—

[Parts per

No.	Date.	Source.	Depth in feet.	Color.	Iron (Fe).
		CARTERET COUNTY—*Continued.*			
34	Sept. 12, 1906	Newport, well of W. S. Bell	73	61	1
35	Sept. 12, 1906	Newport, well	23	0	trace.
		CHOWAN COUNTY—			
36	Nov. 15, 1906	Edenton, flowing well of Dr. Carson	....	39	1
		COLUMBUS COUNTY—			
37	Oct. 23, 1905	Bolton, artesian well of B. W. Brinkley	165	....	trace.
38	Oct. 23, 1905	Bolton, 4 miles northwest of, flowing well of North Carolina Development Co.	70	....	trace.
39	Nov. 10, 1905	Cronly, artesian well of Acme Manufacturing Co.	278	....	.5
40	Oct. 26, 1905	Fairbluff, flowing well of J. W. Powell, 100 ft. south of railroad	300	....	.2
41	Oct. 26, 1905	Fairbluff, artesian well of M. D. Elvington, 250 ft. north of railroad.	200	....	.5
42	Oct. 26, 1905	Fairbluff, well of Anderson Hotel	20	....	1.5
43	Oct. 24, 1905	Hallsboro, flowing well of H. B. Short	125	....	trace.
44	Oct. 24, 1905	Hallsboro, well of H. B. Short	15	....	4
45	Oct. 25, 1905	Hallsboro, flowing well of Hall	85	....	trace.
46	Oct. 24, 1905	Lake Waccamaw, well of H. B. Short	20	....	14
47	Oct. 21, 1905	Lake Waccamaw, flowing well on north shore of the lake; A. C. L. R. R., owner.	80	....	trace.
48	Oct. 21, 1905	Lake Waccamaw, flowing well of H. B. Short, near depot	215	....	trace.
49	Oct. 25, 1905	Old Dock, flowing well of L. E. Thompson	130–140	....	trace.
50	Oct. 25, 1905	Vineland, flowing well of Columbus Trading Co., 75 ft. south of railroad.	185	....	trace.
51	Oct. 23, 1905	Wananish, flowing well of J. P. Council	150	....	trace.
		CRAVEN COUNTY—			
52	Sept. 12, 1906	Blades, well	18	39	trace.
53	Sept. 15, 1906	Cove, deep well near channel	100½	39	trace.
54	Sept. 15, 1906	Dover, well of Goldsboro Lumber Co.	210	66	1
55	Sept. 8, 1906	James City, well of Munger, Bennett & James	38	5	0
56	Sept. 7, 1906	New Bern, city water from 6 wells at pumping station	94	0	trace.
57	Sept. 9, 1906	New Bern, well of J. P. Rodman	72	17	trace.
58	Sept. 7, 1906	New Bern, well at James and Pollok sts.	shallow.	....	0
59	Sept. 7, 1906	New Bern, 3 wells of Pine Lumber Co.	48, 49, 50.	35	1
60	Sept. 8, 1906	New Bern, well on George St., between Pollok St. and Trent River.	shallow.	5	0
61	Sept. 7, 1906	New Bern, well of W. F. Aberly	50	5	0
62	Sept. 12, 1906	North Harlowe, near, flowing well of Joshua Adams	110	69	trace.
63	Sept. 14, 1906	Rheims, well of E. F. Arnold	14	22	trace.
		CUMBERLAND COUNTY—			
64	Oct. 31, 1905	Fayetteville, pond, city of Fayetteville	0	....	.5
65	Nov. 2, 1905	Fayetteville, well on street one block east of market-house	shallow.	....	4
66	Oct. 31, 1905	Fayetteville, spring, one of many feeding city pond	0	....	trace.
67	Oct. 31, 1905	Fayetteville, city water from hydrant	0	....	.5

Continued.

Million.]

Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Analyst.	Remarks.
273	0	15	B. L. Johnson	
134	0	29	B. L. Johnson	Pleistocene. Considerable iron precipitated before analysis.
174	trace.	45	B. L. Johnson	
224	0	14	L. W. Stephenson	Water rises to within 8 ft. of the surface.
162	0	9	L. W. Stephenson	
572	trace.	74.7	L. W. Stephenson	Water rises to within 8 ft. of the surface.
174	trace.	84	L. W. Stephenson	Two aquifers; one at 200 and the other at 300 ft.
99	0	24	L. W. Stephenson	Water rises to within 1 ft. of the surface.
25	trace.	14	L. W. Stephenson	
211	0	14	L. W. Stephenson	
50	trace.	24	L. W. Stephenson	
224	0	14	L. W. Stephenson	
199	0	19	L. W. Stephenson	
224	0	14	L. W. Stephenson	
224	0	14	L. W. Stephenson	
*298	0	14	L. W. Stephenson	
249	0	14	L. W. Stephenson	
199	....	9	L. W. Stephenson	
12	0	15	B. L. Johnson	Pleistocene.
224	0	10	B. L. Johnson	
366	0	10	B. L. Johnson	Peedee formation.
83	trace.	13	B. L. Johnson	In shell-rock.
68	trace.	25	B. L. Johnson	Eocene.
122	trace.	14	B. L. Johnson	
18	trace.	140	B. L. Johnson	
152	trace.	29	B. L. Johnson	
188	trace.	16	B. L. Johnson	
108	trace.	14	B. L. Johnson	
359	0	18	B. L. Johnson	
12	0	20	B. L. Johnson	Pleistocene. Slight precipitation of iron before analysis.
25	0	14	L. W. Stephenson	
....	88	99	L. W. Stephenson	
13	0	14	L. W. Stephenson	
25	0	9	L. W. Stephenson	

*Carbonate radicle (CO_3) 46 parts per million.

TABLE 1—

[Parts per

No.	Date.	Source.	Depth in feet.	Color.	Iron (Fe).
		CUMBERLAND COUNTY—*Continued.*			
68	Nov. 1, 1905	Fayetteville, well of J. M. Wright	237	....	trace.
69	Nov. 1, 1905	Fayetteville, well at ice factory	265	....	1.5
70	Nov. 2, 1905	Fayetteville, well of Stephens	190±	....	trace.
71	Nov. 1, 1905	Fayetteville, Fountain Head Spring	....	....	trace.
72	Oct. 31, 1905	Hope Mills, flowing well of Hope Mills Manufacturing Co.	170	....	2
73	Oct. 31, 1905	Raeford, well of Raeford Hotel	32	....	trace.
		CURRITUCK COUNTY—			
74	Dec. 28, 1906	Currituck, well at courthouse	12	0	0
		DARE COUNTY—			
75	Nov. 22, 1906	Manteo, well of Tranquil House	15	....	0
		DUPLIN COUNTY—			
76	Nov 21, 1905	Bowdens, well of Roland Lumber Co.	213	....	trace.
77	Oct. 11, 1906	Cabin, well near	15±	17	0
78	Oct. 11, 1906	Chinquapin, well of G. B. D. Parker	176	22	0
79	Oct. 11, 1906	Hallsville, flowing well at house of S. O. Middleton	106	17	0
80	Oct. 11, 1906	Kenansville, Famous Spring	0	17	0
81	Nov. 23, 1905	Magnolia, 2 miles southwest of, natural well	0	....	1.5
82	Nov. 22, 1905	Magnolia, artesian well of J. A. Mathis	300	....	trace.
83	Nov. 22, 1905	Magnolia, artesian well of H. E. Newbury	230	....	.5
84	Nov. 24, 1905	Wallace, flowing well of Wallace Manufacturing Co.	80–90	....	trace.
		EDGECOMBE COUNTY—			
85	Oct. 30, 1906	Conetoe, well of C. Wilson	24	22	0
86	Oct. 30, 1906	Old Sparta, 2 miles southeast of, flowing well of Mrs. W. O. Warren.	84	22	0
87	Oct. 31, 1906	Rocky Mount, 6 miles east of, well	61	....	trace.
88	Oct. 31, 1906	Tarboro, flowing well at city waterworks	73	....	3
		GATES COUNTY—			
89	Dec. 28, 1906	Gatesville, well at hotel	22	0	trace.
		GREENE COUNTY—			
90	Oct. 6, 1906	Snow Hill, well	20–25	5	0
91	Sept. 30, 1906	Speights Bridge, well at gin of J. S. Bynum	58	22	0
		HALIFAX COUNTY—			
92	Nov. 3, 1906	Enfield, town well	200	39	.5
93	Nov. 3, 1906	Enfield, well at Hanson's drug store	20	22	trace.
94	Nov. 3, 1906	Enfield, well at graded school	115	39	.5
95	....	Norfleet, well of Patapsco Guano Co.	225	....	....
		HARNETT COUNTY—			
96	Nov. 6, 1905	Dunn, city well	434	0	.5
97	Nov. 11, 1905	Spout Springs, strong spring at base of second railroad cut north of the station.	....	....	trace.

Continued.

Million.]

Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Analyst.	Remarks.
348	0	119	L. W. Stephenson	Said to be from slate rock.
348	0	34	L. W. Stephenson	do.
334	0	34	L. W. Stephenson	From Patuxent formation.
25	0	14	L. W. Stephenson	From Lafayette formation.
249	160	39	B. L. Johnson	
-----------	0	14	B. L. Johnson	
-----------	trace.	0	B. L. Johnson	
36	trace.	35	B. L. Johnson	
149	0	14	L. W. Stephenson	
12	0	49	B. L. Johnson	
249	0	94	B. L. Johnson	
227	0	10	B. L. Johnson	
13	0	25	B. L. Johnson	
199	trace.	19	L. W. Stephenson	A limestone sink; water level is about 30 ft. below the surface. No outlet to well.
199	0	14	L. W. Stephenson	Water rises to within 14 ft. of the surface.
199	0	14	L. W. Stephenson	Water rises to within 25 ft. of the surface.
298	0	19	L. W. Stephenson	
12	0	19	B. L. Johnson	
199	0	19	B. L. Johnson	
12	0	50	B. L. Johnson	
144	0	45	B. L. Johnson	Iron precipitated before analysis.
24	0	19	B. L. Johnson	
12	trace.	61	B. L. Johnson	
146	0	15	B. L. Johnson	
286	0	15	B. L. Johnson	In granite.
-----------	trace.	217	B. L. Johnson	
323	trace.	15	B. L. Johnson	In granite.
*246	trace.	30	B. L. Johnson	The water is drawn from the 170-ft. level.
199	trace.	29	L. W. Stephenson	In rock.
12	----------	9	L. W. Stephenson	

*Carbonate radicle (CO_3) 12 parts per million.

TABLE 1—
[Parts per

No.	Date.	Source.	Depth in feet.	Color.	Iron (Fe).
		HERTFORD COUNTY—			
98	Nov. 10, 1906	Tunis, flowing well of K. R. Israel	165	....	trace.
		HYDE COUNTY—			
99	Nov. 26, 1906	Fairfield, well of J. C. Burrus	80	0	4
100	Dec. 10, 1906	Middleton, well of J. M. Hall	196	96	trace.
		JOHNSTON COUNTY—			
101	Dec. 3, 1905	Smithfield, well of Hood Bros.	110	....	12
102	Dec. 3, 1905	Smithfield, city well at Third and Market sts.	106	....	12
103	Sept. 28, 1906	Smithfield, driven well	15±	22	0
104	Sept. 28, 1906	Smithfield, L. A. Munn's	63	22	0
		JONES COUNTY—			
105	Sept. 20, 1906	Comfort, well of C. A. Rhodes	80	45	0
106	Sept. 22, 1906	Maysville, well of A. J. Collins	68	67	1
107	Sept. 20, 1906	Pollocksville, well on Main St.	30±	5	0
108	Sept. 20, 1906	Trenton, well of Mrs. V. Perry	123	17	0
		LENOIR COUNTY—			
109	Oct. 9, 1906	Kinston, city flowing well	308	22	0
110	Oct. 9, 1906	Kinston, 5½ miles southwest of, flowing well of Jesse Jackson	228	....	0
111	Oct. 8, 1906	Kinston, 2 miles north of, well on terrace escarpment	shallow.	5	0
112	Oct. 5, 1906	LaGrange, well of Robert Jones	25	17	0
113	Oct. 5, 1906	LaGrange, 4 miles east of, flowing well of F. R. Hodges	96	17	0
		MARTIN COUNTY—			
114	Oct. 10, 1906	Williamston, well of Hassell House	15	22	trace.
		MOORE COUNTY—			
115	Nov. 1, 1905	Southern Pines, from ten wells of city waterworks	45±	....	2
116	Nov. 1, 1905	Southern Pines, well of Dr. Sweet	100	....	2
		NASH COUNTY—			
117	Nov. 2, 1906	Nashville, well at courthouse	20	5	0
118	Nov. 2, 1906	Springhope, east of, well	15	5	0
		NEW HANOVER COUNTY—			
119	Oct. 14, 1905	Castle Hayne, artesian well of Wm. Hann, near depot	21	....	13
120	Oct. 14, 1905	Castle Hayne, artesian well of W. H. Shearrin, near depot	70	....	1
121	Oct. 12, 1905	Greenville Sound, well of C. W. Worth	152	....	1
122	Oct. 14, 1905	Wilmington, spring near Front and Wright sts.	0	....	3
123	Oct. 14, 1905	Wilmington, well of Clarendon Water Co. at Hilton Park	0	....	16
124	Oct. 14, 1905	Wilmington, well on Surry St. near Meares St.	80	....	1
125	Oct. 14, 1905	Wilmington, city well at City Hall	70	....	trace.
126	Oct. 14, 1905	Wilmington, spring flowing into quarry near base	0	....	5

Continued.

Million.]

Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Analyst.	Remarks.
----------	trace.	50	B. L. Johnson	
744	0	198	B. L. Johnson	
909	0	208	B. L. Johnson	
99	trace.	14	L. W. Stephenson	
100	trace.	14	L. W. Stephenson	
0	0	15	B. L. Johnson	In sand under clay.
38	trace.	10	B. L. Johnson	In slate.
112	trace.	45	B. L. Johnson	
244	0	20	B. L. Johnson	Develops color and bad odor in bottle. In limestone.
211	trace.	101	B. L. Johnson	
211	0	20	B. L. Johnson	
112	0	15	B. L. Johnson	
124	0	9	B. L. Johnson	
0	0	10	B. L. Johnson	
6.1	0	44	B. L. Johnson	
49	0	9	B. L. Johnson	
0	trace.	64	B. L. Johnson	
0	0	14	B. L. Johnson	
0	0	14	B. L. Johnson	
12	0	111	B. L. Johnson	In decomposed rock.
0	0	10	B. L. Johnson	
298	0	24	L. W. Stephenson	Water rises 6 ft.
298	0	19	L. W. Stephenson	Water rises 58 ft.
274	0	84	L. W. Stephenson	
224	38	74	B. L. Johnson	Eocene limestone rock.
440	530	6,839	B. L. Johnson	
149	0	34	B. L. Johnson	
149	0	29	B. L. Johnson	
118	trace.	27	B. L. Johnson	

TABLE 1—
[Parts per

No.	Date.	Source.	Depth in feet.	Color.	Iron (Fe).
		NEW HANOVER COUNTY—*Continued.*			
127	Oct. 14, 1905	Wilmington, spring in Hilton Park, near Clarendon Waterworks			trace.
128	Oct. 14, 1905	Wilmington, well of Clarendon Waterworks in Hilton Park	1,330		3
129	Oct. 14, 1905	Wilmington, well in ice factory of W. E. Worth & Co.	79		12
130	Oct. 14, 1905	....do.	101		12
131	Oct. 14, 1905	Wilmington, spring at foot of Chestnut St.			trace.
132	Nov. 10, 1905	Wilmington, well of Chadbourn Door and Lumber Co.	88		.5
133	Nov. 13, 1905	Wilmington, well of Angola Lumber Co., ½ mile northwest of waterworks.	60		.5
134	Nov. 13, 1905	Wilmington, 1 mile east of, artesian well of Delgado Cotton Mill	90		trace.
135	Nov. 13, 1905	Wilmington, artesian well of E. L. Holloway, Fifteenth and Market sts.	42		3
136	Nov. 13, 1905	• Wilmington, 1 mile east of, reservoir fed by springs of Delgado Cotton Mill.			.7
137	Oct. 12, 1905	Wrightsville Sound, well of Consolidated Light and Power Co.	172		4.5
		NORTHAMPTON COUNTY—			
138	Nov. 7, 1906	Jackson, well of J. E. Moore	32	5	trace.
139	Nov. 6, 1906	Margarettsville	163	39	2
		ONSLOW COUNTY—			
140	Sept. 24, 1906	Jacksonville, well of H. A. Jarman		5	0
141	Sept. 25, 1906	Jacksonville, flowing well of F. W. Hargett	150	45	trace.
142	Sept. 24, 1906	Richlands, 2 miles south of, well of W. B. Venters	125	5	0
143	Sept. 21, 1906	Richlands, well of W. H. Francks	shallow.	22	0
144	Sept. 22, 1906	Swansboro, well of E. W. Mattocks	28?	5	0
145	Sept. 22, 1906	Swansboro, well of Swansboro Land and Lumber Co.	62	17	trace.
		PAMLICO COUNTY—			
146	Sept. 19, 1906	Arapahoe, well in sandhill region	?	17	0
147	Sept. 20, 1906	Bayboro, well in front of courthouse	52	62	trace.
148	Oct. 27, 1905	Florence, artesian well of A. A. Cohen	350		14
149	Oct. 27, 1905	Florence, city water from hydrant			2.5
150	Sept. 18, 1906	Hobucken, well	9	185+	trace.
151	Sept. 19, 1906	Oriental, well of A. W. Haskins	32	17	0
152	Sept. 18, 1906	Vandemere, flowing well	65	39	0
		PENDER COUNTY—			
153	Nov. 16, 1905	Mill Creek, flowing well of Ed. Sellers on east bank of Black River.	75		trace.
154	Nov. 16, 1905	Atkinson, well of the Jones House	30±		.5
155	Nov. 24, 1905	Willard, artesian well of J. M. Johnson	135		.5
		PITT COUNTY—			
156	Oct. 26, 1906	Farmville, well of C. L. Barrett	65		1.5
157	Oct. 27, 1906	Greenville, two wells at ice factory	157	52	trace.
158	Oct. 27, 1906	Greenville, three flowing wells at Cox's distillery	101-114	27	0

Continued.

Million.]

Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Analyst.	Remarks.
50	0	19	L. W. Stephenson	
398	530	7,218	L. W. Stephenson	
249	0	109	L. W. Stephenson	Water rises 4 ft. above high tide.
273	0	128	L. W. Stephenson	do.
249	50	64	L. W. Stephenson	
199	0	44	L. W. Stephenson	
174	trace.	39	L. W. Stephenson	
199	0	19	L. W. Stephenson	Water rises to within 8 ft. of surface.
174	0	19	L. W. Stephenson	Water rises to within 17 ft. of surface.
99	0	14	L. W. Stephenson	
261	0	131	L. W. Stephenson	Flows a few feet above tide.
20	0	15	B. L. Johnson	
112	trace.	15	B. L. Johnson	
49	0	15	B. L. Johnson	
447	0	20	B. L. Johnson	Odor of H_2S.
136	trace.	15	B. L. Johnson	In limestone.
12	0	20	B. L. Johnson	In sand below clay. Lower water-bearing portion of Pleistocene.
61	trace.	5	B. L. Johnson	
211	0	25	B. L. Johnson	
12	0	15	B. L. Johnson	
366	0	20	B. L. Johnson	Has bad odor.
74	trace.	14	L. W. Stephenson	Water rises to within 24 ft. of surface.
174	trace.	54	L. W. Stephenson	
12	0	38	B. L. Johnson	
100	trace.	20	B. L. Johnson	
435	0	20	B. L. Johnson	Odor of H_2S. Drilled below sea level.
423	trace.	258	L. W. Stephenson	4 miles east of Atkinson.
25	0	14	L. W. Stephenson	
348	0	14	L. W. Stephenson	Rises to within 20 ft. of surface.
87	0	15	B. L. Johnson	
162	trace.	15	B. L. Johnson	
294	0	15	B. L. Johnson	

TABLE 1—

[Parts per

No.	Date.	Source.	Depth in feet.	Color.	Iron (Fe).
		PITT COUNTY—*Continued.*			
159	Oct. 27, 1906	Greenville, flowing well at Cox's distillery	40	27	0
160	Oct. 27, 1906	Greenville, flowing well of American Tobacco Co.	70	40	trace.
161	Oct. 8, 1906	Grifton, well of W. G. Garris	100	22	0
162	Oct. 8, 1906	Grifton, town well near bridge	125	22	0
		RICHMOND COUNTY—			
163	Oct. 28, 1905	Hamlet, well of E. A. Lackey	25	....	2
		ROBESON COUNTY—			
164	Oct. 31, 1906	Dillon, Marion County, S. C., well of J. H. Davis	316	....	0
165	Oct. 24, 1905	Lumberton, well on old fair grounds	52	....	1
166	Oct. 26, 1905	Nichols, village flowing well near the postoffice	170	....	trace.
167	Oct. 31, 1905	Sellers, flowing well at schoolhouse	250?	....	1 2
		SAMPSON COUNTY—			
168	Nov. 16, 1905	Alpine, flowing well of F. R. Corbett	71	....	trace.
169	Nov. 18, 1905	Clear Run, flowing well of A. J. Johnson	72	....	1
170	Nov. 20, 1905	Clinton, city well	16±	....	trace.
171	Nov. 20, 1905	Clinton, well of Montague Hotel	22±	....	trace.
172	Nov. 16, 1905	Ivanhoe, flowing well of Mrs. M. C. McMillan	65±	....	7
173	Nov. 20, 1905	Kennedy's Mills, flowing well of J. J. Kennedy	44	....	1 5
174	Nov. 20, 1905	Thomas, flowing well of J. E. Rich	75	....	trace.
		TYRRELL COUNTY—			
175	Nov. 13, 1906	Columbia, well of B. F. Cox	22	....	trace.
		WASHINGTON COUNTY—			
176	Oct. 22, 1906	Plymouth, town well	190±	35	0
177	Oct. 22, 1906	Plymouth, well of Levy Blount	22	22	0
178	Oct. 27, 1906	Roper, flowing well of T. W. Blount	225+	....	0
		WAYNE COUNTY—			
179	Oct. 3, 1906	Goldsboro, 5 miles north of, well	22	23	0
180	Oct. 3, 1906	Goldsboro, flowing well of E. B. Borden	35	22	0
181	Oct. 5, 1906	Goldsboro, well at Southerland Stables	?	22	0
182	Nov. 21, 1906	Mount Olive, in vicinity of, well of D. L. Flowers	151	....	trace.
183	Nov. 21, 1906	Mount Olive, in vicinity of, well of W. F. Martin	72	....	2
184	Nov. 21, 1906	Mount Olive, in vicinity of, well of W. J. Flowers	43	....	6
185	Nov. 21, 1906	Mount Olive, in vicinity of, well of Asher Flowers	40	....	3
		WILSON COUNTY—			
186	Dec. 16, 1906	Elm City, near, dug well	shallow.	27	trace.
187	Dec. 16, 1906	Wilson, well of Clark Plate Ice Co.	216	22	trace.
188	Dec. 16, 1906	Wilson, well at Pepsi-Cola Bottling Works	200	42	trace.

Continued.

Million.]

Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Analyst.	Remarks.
0	trace.	15	B. L. Johnson	
136	trace.	35	B. L. Johnson	
174	0	10	B. L. Johnson	In shell-rock.
174	0	14	B. L. Johnson	
0	0	19	B. L. Johnson	
122	0	10	L. W. Stephenson	In Marion County, S. C., but conditions similar to those in Robeson County, N. C.
149	0	14	B. L. Johnson	
99	0	14	L. W. Stephenson	In Marion County, S. C., but conditions similar to those in Robeson County, N. C.
122	0	14	L. W. Stephenson	
211	0	10	L. W. Stephenson	
136	trace.	10	L. W. Stephenson	
122	0	132	L. W. Stephenson	
122	0	49	L. W. Stephenson	
249	0	14	L. W. Stephenson	
25	0	10	L. W. Stephenson	4 miles north of Thomas.
50	0	10	L. W. Stephenson	
49	0	25	B. L. Johnson	
397	trace.	178	B. L. Johnson	Odor of H_2S.
158	trace.	103	B. L. Johnson	In sand and under clay.
548	trace.	138	B. L. Johnson	
24	0	15	B. L. Johnson	In sandy slate.
62	0	10	B. L. Johnson	
24	trace.	30	B. L. Johnson	
112	0	10	L. W. Stephenson	In Patuxent formation.
48	0	19	L. W. Stephenson	In Black Creek formation.
25	0	14	L. W. Stephenson	
37	0	10	L. W. Stephenson	In Black Creek formation.
10	0	25	B. L. Johnson	In sand below clay.
137	trace.	5	B. L. Johnson	In granite.
124	trace.	5	B. L. Johnson	do.

TABLE 2—MINERAL ANALYSES OF NORTH

[Parts per

No.	Date.	Source.	Depth in feet.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).
		BEAUFORT COUNTY—					
1		Belhaven, one of three wells of the Interstate Cooperage Co.	100	14	0.3	59	17
2		Belhaven, well of Belhaven Ice Co	96	37	14	81	22
3		Leechville, 3 miles north of well of D. C. Way Co.	308		2.3	12	16
4		Washington, well of Washington Municipal Electric Light and Power Co.	90-100	5.6	1.2	88	5.2
5		Washington, 3 miles northeast of Cowhead Spring		50	4.3	12	19
		BERTIE COUNTY—					
6		Windsor, flowing well at	250	16	0.3	1.4	trace.
		BLADEN COUNTY—					
7		Bladenboro, flowing well near bridge R. S. and H. C.		6.6	trace.	9	0.8
		BRUNSWICK COUNTY—					
8		Fort Caswell, well No. 1	800	6.4	7.0	9	31
9		Fort Caswell, well No. 2	1,442	5.6	8.4	598	40
10		Quarantine station, well at*	400	9.4	1.7	27	4
11		do					
12		do					
13		do					
14		do					
15		do					
16		do					
17		do					
18		do					
19		do					
20		do					
21		do					
22		do					
23		do		15	trace.	57	9.6
		CHOWAN COUNTY—					
24		Edenton, well city waterworks	212	8.6	0.4	66	19
		COLUMBUS COUNTY—					
25	Dec. 13, 1906	Lake Waccamaw, flowing well on shore of lake	80	9.4	trace.	29	1.2
		CRAVEN COUNTY—					
26	Dec. 5, 1906	New Bern, well of New Bern Ice Co.	38	8.4	0 1	137	6.8
		DARE COUNTY—					
27	Nov. 26, 1906	Hatteras, well	6	8.8		1 0	0.8

*For explanation of tests 10 to 23 inclusive, see p. 485.

CAROLINA COASTAL PLAIN WATERS.

Million.]

Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Organic and volatile.	Total dissolved solids.	Analyst.	Remarks.
92 + 7	trace.	475	trace.	.16	9	....	472	J. R. Evans.....	Miocene.
25	185	....	13	....	16	....	398	Harrison Safety Boiler Works (?)	
298 +38	....	....	122	....	146	....	1,100	F. P. Venable...	PO_4, trace. Mn 6.
31	114	....	53	....	45	8.9	353	Dearborn Laboratories.	
9.4+ .9	....	....	23	....	7.4	....	....	F. P. Venable...	Mn 5.8. PO_4 0.3.
175 +12	26	342	60	.06	38	....	567	J. R. Evans.....	Odor of H_2S.
8.8	....	39	trace.	.03	5	....	62	J. R. Evans.....	
4,963	67	122	22	....	7,840	....	13,330	J. R. Evans.....	
6,343	....	1,037	27	....	10,400	....	17,634	J. R. Evans.....	
100	....	71	43	....	168	....	364	J. R. Evans.....	10:54 A. M.
....	....	305	....	....	7,300	....	....	J. R. Evans.....	10:57 A. M.
....	....	326	....	....	8,800	....	....	J. R. Evans.....	11:00 A. M.
....	....	245	....	....	460	....	....	J. R. Evans.....	11:05 A. M.
....	....	220	....	....	285	....	....	J. R. Evans.....	11:10 A. M.
....	....	205	....	....	260	....	....	J. R. Evans.....	11:15 A. M.
....	....	195	....	....	256	....	....	J. R. Evans.....	11:20 A. M.
....	....	193	....	....	250	....	....	J. R. Evans.....	11:25 A. M.
....	....	189	....	....	245	....	....	J. R. Evans.....	11:30 A. M.
....	....	188	....	....	245	....	....	J. R. Evans.....	11:35 A. M.
....	....	187	....	....	240	....	....	J. R. Evans.....	11:40 A. M
....	....	188	....	....	235	....	....	J. R. Evans.....	11:45 A. M.
....	....	192	....	....	240	....	....	J. R. Evans.....	11:50 A. M.
165 +trace.	....	190	5.9	....	242	....	600	J. R. Evans.....	12:00 M.
101 + 6.5	trace.	493	20	.06	2	....	540	J. R. Evans.....	
20	trace.	183	2.8	....	4.5	....	154	J. R. Evans.....	
105 + 2	....	427	36	12	129	....	638	J. R. Evans.....	
39 + .5	....	9.7	23	.03	38	....	117	J. R. Evans.....	

TABLE 2—

[Parts per

No.	Date.	Source.	Depth in feet.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Ma[illegible] (Mg).
		HALIFAX COUNTY—					
28	....	Littleton, 1 mile north of Hygeia Spring	....	24	3.2	2.3	[illegible]
29	....	Panacea, Panacea Springs	....	....	29	14	[illegible]
30	....	....do	....	15	....	5	[illegible]
		HERTFORD COUNTY—					
31	....	Murfreesboro, 1½ miles from Lawrence Spring No. 1	....	24	1.1	3.7	[illegible]
32	....	....do	....	20	1.5	5.1	[illegible]
33	....	Murfreesboro, fair grounds (Wise) spring	....	21	1.3	6.5	[illegible]
		HYDE COUNTY—					
34	Nov. 26, 1906	Fairfield, well of J. A. Mann	240	10	4	50	[illegible]
35	Nov. 26, 1906	Middleton, public flowing well	204	15	12	6.5	[illegible]
		JOHNSTON COUNTY—					
36	Aug. 17, 1907	Selma, well at factory	....	....	4.2	27	[illegible]
		LENOIR COUNTY—					
37	Dec. 6, 1906	Kinston, well of J. H. Bell	13	6.2	0.2	9.8	[illegible]
38	Dec. 6, 1906	Kinston, city well	308	8.4	0.0	3.1	trace.
		MOORE COUNTY—					
39	Dec, 3, 1906	Southern Pines, well	100	7.2	0.0	1.1	trace.
		NEW HANOVER—					
40	Dec. 12, 1906	Wilmington, flowing salt well, Clarendon W. W.	1011–1019	6.8	0.7	142	[illegible]
41	Dec. 14, 1906	Wilmington, well of Universal Oil and Fertilizer Co.	....	5.4	0.0	56	[illegible]
		ONSLOW COUNTY—					
42	....	Catharine Lake, 1½ miles south of Catharine Lake Spring	....	22	2.2	16	[illegible]
		PITT COUNTY—					
43	Dec. 6, 1906	Greenville, flowing well	100	6.8	0.1	15	[illegible]
		ROBESON COUNTY—					
44	Dec. 2, 1906	Red Springs, flowing well	102	2.4	2	1.3	[illegible]
45	....	Red Springs, mineral spring No. 1	....	8	7.2	2.1	[illegible]
46	....	Red Springs, mineral spring No. 2	....	11	10	3.4	[illegible]
47	....	Red Springs, flowing well No. 1	....	13	5.2	1.8	1
48	....	Red Springs, flowing well No. 6	?	13	5.0	1.8	[illegible]
		RICHMOND COUNTY—					
49	....	Rockingham, 12 miles north of Ellerbe Spring	?	30	2.8	15	4.6
		SAMPSON COUNTY—					
50	Dec. 14, 1906	Clear Run, west of Black River, well	85	4.8	0.0	24	[illegible]

Continued.

Million.]

Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Organic and volatile.	Total dissolved solids.	Analyst.	Remarks.
0.6+ 3.7			0.5		5.5			F. P. Venable	MnO .4. PO_4 12.
28 +10			7.9		14				MnO .17. Al. 2.9
3.5			0.4		5.5			F. P. Venable	Mn 2.9.
2.4+trace			20		4			F. P. Venable	200 yds. from spring No. 2. PO_4, trace. Mn 2.8.
3.4+ .7			13		6.4			F. P. Venable	Mn 1.8.
21 + 1.1			6.7		18			F. P. Venable	Mn 3.4. PO_4, trace.
2,027 + 9.6	0	751	317	.23	2,860		4,768	J. R. Evans	
477 + 4.6	14	818	18	.13	210		1,179	J. R. Evans	
6.2+ 3.1	41		3.9		9.7			F. B. Carpenter	
15	0	30	11	.08	44		155	J. R. Evans	
37 + 1.6	7.2	107	0	.02	3			J. R. Evans	
3.4	0	7.6	4.1	.15	0.5		28	J. R. Evans	
5,186 +40		361	404	.03	7,400		14,752	J. R. Evans	
43	4.8	205	3.3	.08	42		272	J. R. Evans	
3.2+ .5			7.8		6.2			F. P. Venable	Mn 1.8. PO_4 13.
47 + 1.5	22	146	0	.16	0			J. R. Evans	
21	0	22	6.6	.10	15		64	J. R. Evans	
2.9+ 2.0	30		2.4		1.3	9.2		Dancy and Harris.	
2.6+ 3.1	44		2.9		.7	2.6		Dancy and Harris.	
2.4+24			2.3		.8			F. P. Venable	H_2S, trace. Mn 1.5. Pipe driven 20 to 25 ft. in ground.
1.6+ .2			1.8		4.4			F. P. Venable	
4			5.7		6			F. P. Venable	
2	0	115	3.9	.00	8.5		165	J. R. Evans	

TABLE 2—

[Parts per

No.	Date.	Source.	Depth in feet.	Silica (SiO₂).	Iron (Fe).	Calcium (Ca).	Magne-[illegible]
		WAYNE COUNTY—					
51	....	Seven Springs, seven springs within space 10′ by 5′, Spring No. 1.	....	15	4	2.8	[illegible]
52	....	Seven Springs, seven springs within space 10′ by 5′, Spring No. 2.	....	14	2.6	2.5	[illegible]
53	....	Seven Springs, seven springs within space 10′ by 5′, Spring No. 3.	....	15	1.7	1.9	[illegible]
54	....	Seven Springs, seven springs within space 10′ by 5′, Spring No. 4.	....	15	3.2	1.7	[illegible]
55	....	Seven Springs, seven springs within space 10′ by 5′, Spring No. 5.	....	16	1.4	2.7	[illegible]
56	....	Seven Springs, seven springs within space 10′ by 5′, Spring No. 6.	....	13	1.8	2.7	[illegible]
57	....	Seven Springs, seven springs within space 10′ by 5′, Spring No. 7.	....	17	4.5	2.8	[illegible]
		WILSON COUNTY—					
58	Dec. 16, 1906	Moyeton, near, flowing well	....	9.2	trace.	16	[illegible]

Continued.

Million.]

Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Organic and volatile.	Total dissolved solids.	Analyst.	Remarks.
3.4+ .5				11	5.4			F. P. Venable	Mn, trace.
2 0+ .7				12	4.6			F. P. Venable	Mn, trace. PO_4, trace.
4.5+ 1.0				9.2	7.0			F. P. Venable	Mn, trace. PO_4, trace.
3.1+ 1.2				5.8	4.8			F. P. Venable	Mn, trace. PO_4, trace.
2.7+ 0.5				12	4.2			F. P. Venable	Mn, trace. PO_4, trace.
3.0+ 0.7				11	4.6			F. P. Venable	PO_4, trace.
2.7+ 0.5				12	4.2			F. P. Venable	PO_4, trace.
60 + 3		207	16	.16	17		276	J. R. Evans	

GENERAL INDEX.

A

E

F

H

PALEONTOLOGICAL INDEX.

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